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INSTRUCTION MANUAL
MODEL 304
WAVE AND NOISE SPECTRUM ANALYZER

FOR SERIAL # _____

Quan-Tech
DIVISION OF KMS INDUSTRIES, INC.

INSTRUMENTS • AMPLIFIERS • NOISE INSTRUMENTATION

INSTRUCTION MANUAL
MODEL 304
WAVE AND NOISE SPECTRUM ANALYZER

FOR SERIAL # _____

Quan-Tech®
DIVISION OF KMS INDUSTRIES, INC.

43 SOUTH JEFFERSON ROAD WHIPPANY, NEW JERSEY 07981

201-887-5508

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CLAIM FOR DAMAGE IN SHIPMENT

The instrument should be tested as soon as it is received. If it fails to operate properly, or is damaged in any way, a claim should be filed with the carrier. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will then advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY

Quan-Tech Laboratories, Inc. warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electronic tubes and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid by the original purchaser, and when upon our examination it is disclosed to our satisfaction to be defective. If the fault has been caused by misadjustments, misuse, or abnormal conditions of operation, repairs will be billed at cost. In this case, an estimate will be submitted before the work is started.

Calibration checks of this instrument can easily be made in accordance with the instruction manual. Routine readjustments should never be attempted. If, however, the instrument has been damaged and requires recalibration or alignment, explicit calibration procedures as defined in the instruction manual must be followed.

If any fault develops, the following steps should be taken:

1. Notify us, giving full details of the difficulty, and include the model number and serial number. On receipt of this information, we will give you service data or shipping instructions.

2. On receipt of shipping instructions, forward the instrument prepaid, to the factory. If requested, an estimate of the charges will be made before the work begins provided the instrument is not covered by the warranty.

SHIPPING

The instruments should be packed in their original containers, or in a strong exterior container and surrounded by two inches of shock absorbing material.

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FRONT VIEW
MODEL 304
Wave and Spectrum Analyzer

SECTION 1

GENERAL

A. DESCRIPTION

The Model 304 is one of the most versatile analytical instruments ever designed. It is not only useful as a standard wave analyzer for harmonic measurements and Fourier analysis of complex signals, but its three selectable flat-top bandwidths make it ideally suited for spectral density analysis of random signals. In addition, when used with an X-Y plotter, it can automatically plot the phase and amplitude characteristics of an electronic or electromechanical system.

The Model 304 features electronic tuning, using an extremely stable and precise voltage controlled oscillator. A 5000 division linear scale is provided for manual tuning. Internal variable speed sweep circuits permit automatic scanning of the entire, or discrete portions of the frequency range. The frequency may also be controlled from an external voltage source for remote tuning or sweeping.

When used with an oscilloscope, X-Y plotter, or strip-chart recorder the Model 304 becomes a spectrum analyzer whose center frequency, sweep width, and resolution can all be varied over wide limits. Averaging time, bandwidth, and sweep speed can be selected for optimum results in random signal analysis.

The versatility of the Model 304 is increased by a multiplicity of outputs; BFO, restored signal, meter and frequency analogs are available at front panel jacks and at a connector in the rear of the chassis. Also available at the rear connector are phase outputs, the sweep voltage and remote tuning input connections. A pen-lift circuit can be supplied as an optional feature.

When used with a minimum of associated equipment, the Model 304 becomes a complete system for analyzing low frequency phenomena. Typical applications include vibration analysis, medical applications, underwater sound, or any other random or repetitive signal.

B. SPECIFICATIONS

FREQUENCY

Range: 1 cycle to 5000 cycles.
Accuracy: ± 0.5% or 1 cycle.
Dial: Linear, one cycle per division

SELECTIVITY

Three pass bands, 1 cycle, 10 cycles, and 100 cycles at 3db down, selectable by front panel switch. Maximally flat 4 section Butterworth type with 24db slopes.

SENSITIVITY

Range: 30μV to 100 volts full scale in 10db steps. Also variable gain control of 20db.
Dynamic Range: >70db for Fourier analysis, >40db for random signal analysis.
Accuracy: ±5%

INPUT IMPEDANCE

100K ohms.

AVERAGING TIMES

Approximately < 0.1, 1, 10 and 100 seconds, switch selectable.

SWEEP FUNCTIONS

Time: 18, 180 or 1800 seconds, switch selectable.
Increment: 50, 100, 500, 1000 or 5000 cps, switch selectable.
Modes: Single, repetitive or external.

SWEEP OUTPUT

0 to +5v for any frequency increment selected by the sweep control.

FREQUENCY ANALOG

DC output proportional to frequency to which system is tuned.
1MV/cycle, +5V max.

EXTERNAL SWEEP INPUT
1MV to +5V for 1 to 5000 cycles.

METER ANALOG
0 to +10V D.C. proportional to meter deflection. (output clamped to ground during sweep retrace)

CARRIER OUTPUT
The undetected 10Kc carrier equal to the input signal amplitude. Nominally 0.1 VRMS for a full scale signal.

BFO OUTPUT
Sine wave output of the frequency to which the instrument is tuned.
Will deliver nominally 1VRMS into 600 ohms.

RESTORED FREQUENCY OUTPUT
The filtered input signal as determined by tuning and bandwidth selected.
Will deliver nominally 0.5VRMS into 600 ohms for a full scale meter reading.

PHASE OUTPUTS
In-phase and quadrature components of filtered input signal, each capable of at least 1 volt peak-peak.

POWER INPUT
117/234 VAC, 50-400 Hz, 12 Watts or
2 External batteries each 20 to 32V D.C. @200 MA per hour.

DIMENSIONS
11-1/16" x 15" x 11-1/4". Weight 26 lbs.

C. ACCESSORIES

Two Type 1112 Cables are supplied with each instrument.

OPERATION

A thorough understanding of an instrument and its principle of operation greatly enhances its usefulness. The Model 304 Wave and Spectrum Analyzer is a precision instrument capable of performing accurate signal analysis. For the most effective application of this equipment we strongly recommend that the prospective operator read Section 3, the Theory of Operation, before using the instrument.

A study of both the block diagram and the following description, along with the panel markings, will help to familiarize the operator with the functions of the various panel controls.

A. DESCRIPTION OF CONTROLS

1. TUNING – The COARSE, FINE and ZERO controls each, by means of electro-mechanical linkage, can change the frequency of a voltage-controlled oscillator (VCO) thereby tuning the instrument. The controls differ in both range and resolution but are alike in that each control precisely converts angular motion to a change in frequency of the VCO.

Listed below is the range and resolution of each:

COARSE – 5 KC max., 350 cps/rev.
FINE – 5 KC max., 100 cps/rev.
ZERO – 200 cps max., 20 cps/rev.

2. SENSITIVITY – The METER MULTIPLIER, VARIABLE GAIN and MILLIVOLTS FULL SCALE controls set the instrument's sensitivity and provide for a combined range of 130 db. The METER MULTIPLIER and VARIABLE GAIN controls are associated with the input circuits and serve to adjust the input signal level to the correct value for analysis. The MILLIVOLTS FULL SCALE switch is in essence a range switch for the voltmeter. The sensitivity of the analyzer is increased in 10 db increments as this control is rotated counter-clockwise. For absolute amplitude measurements, the 20 db VARIABLE GAIN control should be rotated clockwise to the CALIBRATED position. The meter will then read directly in millivolts x the METER MULTIPLIER.

3. SELECTIVITY – The overall passband of the system is controlled by the BANDWIDTH switch and may be set to 1, 10 or 100 cycles. Refer to the curves in Figure 2 for typical filter response characteristics.

4. METERING – The METER T.C. switch provides for the selection of meter averaging times. The operator will find it helpful in that the averaging time can be changed by the same ratio as the system bandwidth namely, 10:1. The selectable averaging time is of particular usefulness in the measurement of noisy signals.

The METER ZERO controls provide a means of periodically balancing critically matched circuits which are subject to change with time and temperature. Circuit unbalance is indicated by a finite meter reading with no signal applied and should be "zeroed out" for correct operation.

For recording purposes, the METER ANALOG voltage is made available at a jack on the front panel.

5. SWEEP – In addition to manual control of the VCO, provision has been made to electronically tune it with the built-in ramp generator. Using the SWEEP controls, the operator may vary the scan-rate from 0.03 to 300 cps. The SINGLE/AUTO/RESET switch provides for single or repetitive scanning and the sweep voltage is made available at the SWEEP ANALOG jack for operating oscilloscopes, recorders, etc.

6. BFO AND RESTORED – Either of these signals may be selected and its amplitude adjusted by the two controls provided. The BFO is a sine wave equal to the frequency to which the instrument is tuned, whereas the RESTORED signal is equal to to the input signal after it has been passed through a 1, 10 or 100 cycle filter and therefore is only available when the instrument is tuned to an input signal.

7. PHASE/NORMAL – Although this switch is located on the back of the instrument, it is no less important than the others. The purpose of this control is to short out the 5 KC filter, associated with the input circuit, when making phase measurements. This minimizes the overall system phase shift. It is imperative that this switch be in the NORMAL position when making measurements other than phase response.

B. INITIAL OPERATION

1. Connect the instrument to a suitable source of power.
   a. AC Operation. Refer to plate located near the power cord for the voltage and frequency for which the instrument is wired. (See Section 4)
   b. DC Operation. Connect 2 batteries, each 20-32VDC @ 200 MA per hour to J801 at rear of instrument. See Schematic, T-4408 for pin connections.
   CAUTION: AC power cord MUST NOT be connected to a source of power.
2. Allow at least 10 minutes for the instrument to stabilize before making any adjustments.
3. Calibrate the dial for frequency accuracy as follows:
   a. Set panel controls as indicated below:
      (1) MILLIVOLTS FULL SCALE. 30
      (2) METER TC. . . . . <.1
      (3) VARIABLE GAIN. . . . . .CALIBRATED
      (4) METER MULTIPLIER. X1
      (5) BANDWIDTH. 100
      (6) FREQUENCY DIAL. 000
      (7) SWEEP. . . . . .OFF
      (8) PHASE/NORMAL switch . . . .NORMAL
   b. Tune the FREQUENCY ZERO control for a maximum meter reading (less than 40 MV).
   c. Set BANDWIDTH to 10 cycles and again peak meter reading.
   d. Switch to a bandwidth of 1 cycle and very slowly adjust the FREQUENCY ZERO for a maximum meter reading. A low frequency beat will occur if the meter zero has not been adjusted.
4. Zero the meter as follows:
   a. Set the dial such that the instrument is tuned neither to an incoming signal nor the 000 carrier.
   b. Turn the MILLIVOLTS switch counter-clockwise to progressively more sensitive ranges. As the sensitivity of the instrument is increased, a residual voltage may be discernible. Alternately adjust the METER ZERO controls for a minimum meter reading; adjusting for the best possible null on the most sensitive range. (This should be less than 1% of full scale.)

– NOTE –

The instrument is now ready for operation. However, for best performance the above procedure should be repeated periodically.

C. MANUAL OPERATION

Since the exact procedure for operating the controls depends in large part on the nature of the test to be performed, consider the following example of manual operation.

A one volt, one Kc signal is to be analyzed for harmonic distortion:

1. Set the MILLIVOLT FULL SCALE switch to 1000.
2. Set the METER MULTIPLIER switch to X1.
3. Turn the VARIABLE GAIN control clockwise to the CALIBRATED position.
4. Select a METER T.C. of <.1 secs.
5. Set the BANDWIDTH to 100 cycles.
6. Tune the FREQUENCY dial to 1000 cps.
7. Connect the signal to the INPUT.
   a. The black post is grounded.

The meter should read approximately full scale if not, adjust the VARIABLE GAIN control such that it does. The exact frequency may be more nearly determined by switching to the 10 cycle bandwidth and re-tuning.

Now that both the amplitude and frequency of the fundamental signal are known, measure the second harmonic content by setting the dial to twice the fundamental frequency (approx. 2Kc). Rotate the MILLIVOLTS FULL SCALE switch counter-clockwise until the meter reads up scale. This measure of the second harmonic may now be related to the fundamental signal by expressing its magnitude in percentage of, or decibels below one volt. Similarly by successively tuning to 3000, 4000 and 5000 cps the magnitude of the third, fourth and fifth harmonics of the fundamental may be measured.

D. AUTOMATIC MODE

1. Set FREQUENCY dial to the frequency at which the sweep is to start.
2. Select the SWEEP width; 50, 100, 500, 1000 or 5000 cps.
3. Set the SWEEP time (See Note).
   a. SLOW. . . . . 1800 seconds
   b. MED. . . . . .180 seconds
   c. FAST. . . . . 18 seconds
4. Select the bandwidth and metering time constant as required. (See Note).
5. To initiate the sweep, operate the sweep mode switch first to RESET then back to either the AUTO or SINGLE positions.
   a. AUTO - Instrument will continuously scan the selected frequency range.
   b. SINGLE - Instrument will make one scan, stopping at the top of the selected frequency range. The unit will then maintain this tuning until manually detuned or reset.

NOTE:

In the interest of providing maximum versatility, the bandwidth, sweep, and averaging time controls have not been interlocked such as to always provide maximum accuracy. The operator must therefore consider with care his choice of settings.

The field of waveform and spectrum analysis is both broad and complex. There are, however, several excellent texts and articles published on the subject and therefore no attempt will be made in this short manual to cover it thoroughly; instead listed below are a number of basic formulae and notes intended merely to serve as a guide to the effective usage of the equipment.

1. SCAN RATE (cps) = $\frac{\text{Sweep width (cycles)}}{\text{Sweep time (seconds)}}$

   or $SR = \frac{W}{T}$

2. The maximum SR, with regard to bandwidth, should not exceed the following formula:

   $$SR_{(Max)} = \left(\frac{BW}{2}\right)^2$$

   This refers to the analysis speed limitation imposed by the system bandwidth and can be violated only at the expense of accuracy.

3. The averaging time (METER T.C.) should be selected according to the accuracy requirements of the particular test. In the case of pure random noise, the statistical error (e) due to finite filter bandwidth and averaging time may be estimated by:

   $$e = \frac{1}{\sqrt{8BW \times TC}}$$

   where:

   e = Probable error
   BW = Effective filter bandwidth
   TC = Meter time constant

E. PHASE MEASUREMENTS

An extremely useful feature of the Model 304 is its capability of supplying analogs of both the real and imaginary portions of the input signal when the specimen under test is excited by the BFO. The significance of this is, of course, that if these two dc voltages are simultaneously plotted against one another, a polar diagram will result - from which the phase response characteristics of the specimen may be determined (see Figure 4). The information can be displayed on either an oscilloscope or an X-Y recorder and the specimen may range from a simple network to a complex electro-mechanical system. Furthermore, the testing can be performed manually or automatically depending on the setting of the sweep controls.

1. ACCURACY – No attempt has been made to normalize the phase response of the basic model 304 itself, however, the system phase shift is quite linear with frequency, (approx. 27 deg./Kc) and therefore it can be readily subtracted from the total. Another method more suitable for incremental phase measurements would be to make the desired plot using an X-Y recorder and calibrated paper, then on the same paper, plot the system phase shift. Mechanical normalization can result in accuracies of a fractional degree.

2. EXAMPLE – Consider measuring the phase response of a bandpass filter centered at 1 Kc and having a bandwidth of 100 cps.

   a. Set the PHASE/NORMAL switch to PHASE.
   b. Calibrate the dial and zero the meter.
   c. Connect the BFO to the filter input and connect the filter output to the input terminals of the Model 304.
   d. Set the FREQUENCY dial to 1000 cps and the BANDWIDTH to 10 cps.
   e. Adjust the BFO to the desired level, keeping it as high as is practical.
   f. Adjust the input attenuators and meter sensitivity controls such that the meter reads up-scale.
   g. With no signal input, establish the X and Y axes on the paper, adjust the recorder sensitivity (j and R each = approx. 0.6V pk. for a full scale meter reading) and set the pen at the origin.
   h. Connect the outputs of the Model 304 to the recorder inputs, j to X and R to Y. With the pen lifted make a dry-run to check equipment connections, sensitivities, etc. The final test can then be made by scanning the spectrum of interest either manually or automatically.

SECTION 3

THEORY OF OPERATION & CIRCUIT DESCRIPTION

A. THEORY OF OPERATION

The Model 304 is basically a dual conversion heterodyne receiver having a 10 Kc first IF and a zero center frequency second IF.

Referring to the Block Diagram, Figure 1, the incoming signal is filtered to remove frequencies above 5 Kc and then mixed with the output of the 10 to 15 Kc variable oscillator. The difference frequency is passed through the 10 Kc first IF to a pair of second modulators. The two second modulators are driven 90° out of phase by a two phase 10 Kc fixed oscillator. The difference frequencies are then passed through a pair of active low pass filters with selectable cut-off frequencies of 0.5, 5, and 50 cycles.. Since the center frequency of the second IF is zero (DC) and the difference signals can go plus and minus, the resultant bandwidths are 1, 10, and 100 cycles. The low frequency filtered signals are then chopped at 10 Kc, again 90° out of phase, and recombined in a summing circuit. An amplifier and rectifier drives the meter and meter analog.

The Restored Signal output is a filtered replica of the input signal exactly equal in frequency and proportional in amplitude. It is obtained by mixing the summed 10 Kc signal with the variable oscillator output and taking the difference frequency.

The BFO output is a constant amplitude signal of exactly the frequency to which the instrument is tuned. It is obtained by mixing the 10 Kc fixed oscillator with the 10-15 Kc variable oscillator and again taking the difference frequency.

Phase information is obtained from the Model 304 by means of the following principle. If two signals of the same frequency are mixed in a balanced modulator, a DC output will be obtained that is proportional to the phase angle between the signals. At zero degrees, the output is maximum and of one polarity. At 90° the output is zero. At 180° it is again maximum, but of the opposite polarity, and at 270° (-90°) again zero. Referring again to the Block Diagram, the BFO modulator is driven from the same phase of the 10 Kc fixed oscillator as the R channel and 90° out of phase with the j channel. Since the BFO modulator and the first modulator are both driven from the same phase of the variable oscillator, if the output of the BFO without phase shift is connected to the input of the Model 304, it will arrive at the second modulator as a 10 Kc signal in phase with the R channel. Since it is in phase with the R channel and 90° out of phase with the j channel, there will be R output but no j output. If phase shift is introduced between the BFO output and the input to the 304, the R output will decrease and the j output increase until at 90° there will be no R output and maximum j output. In this way the Model 304 can separate the real from the imaginary parts of a voltage derived from a device driven by the BFO output.

B. CIRCUIT DESCRIPTION

1. +15 VOLT POWER SUPPLY: SCHEMATIC, T-4401 — The +15 Volt Power Supply obtains its reference from CR104. This reference voltage is compared with the output voltage as determined by the resistor divider, R104 and R105. Any difference between these two voltages is amplified by the double differential amplifier consisting of Q101, Q102, Q103 and Q104. The resulting output error signal drives the pass transistor, Q105, which maintains a constant output voltage. Additional regulation for changes in line voltage is accomplished by the reference diode, CR103.

2. −15 VOLT SUPPLY: SCHEMATIC T-4402 The −15 Volt Supply is identical to the +15 Volt Supply with the exception that the positive output terminal is grounded rather than the negative.

3. ATTENUATOR, PREAMPLIFIER AND 5 KC LOW PASS FILTER: SCHEMATIC T-4403 The input attenuator is a straightforward 100,000 ohm resistor divider. The preamplifier consists of three transistors, Q301 and Q302 both being voltage amplifiers and Q303 operating as an emitter follower. Gain stability is achieved using heavy feedback and

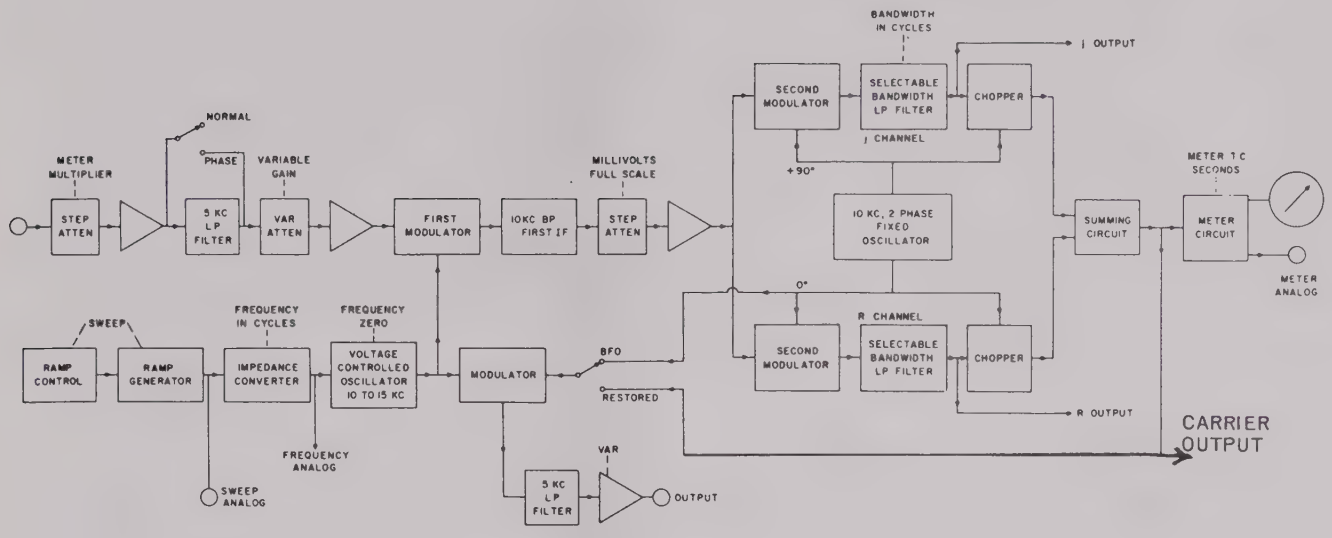


Figure 1 BLOCK DIAGRAM MODEL 304

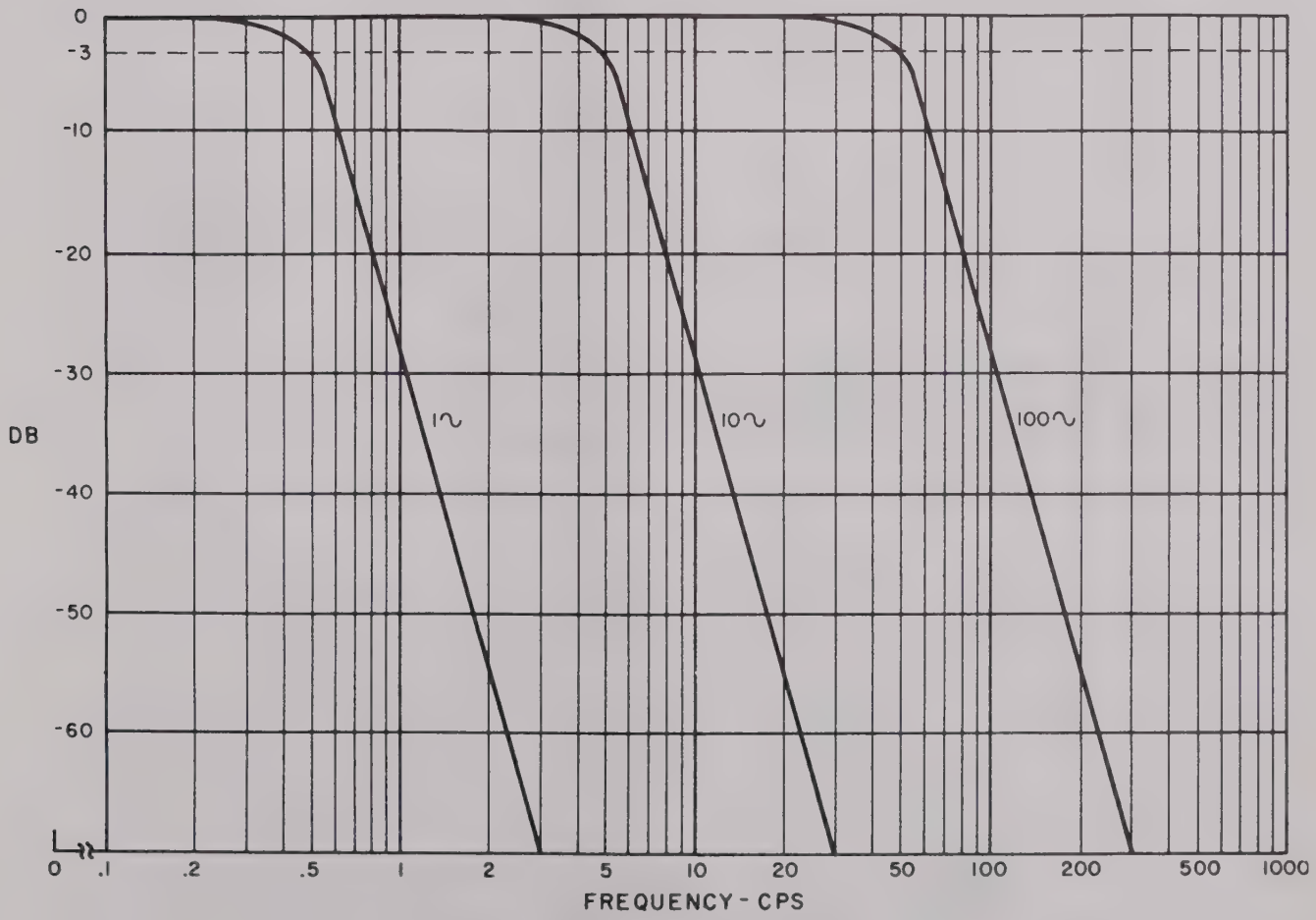


Figure 2 **TYPICAL HALF-BAND RESPONSE**

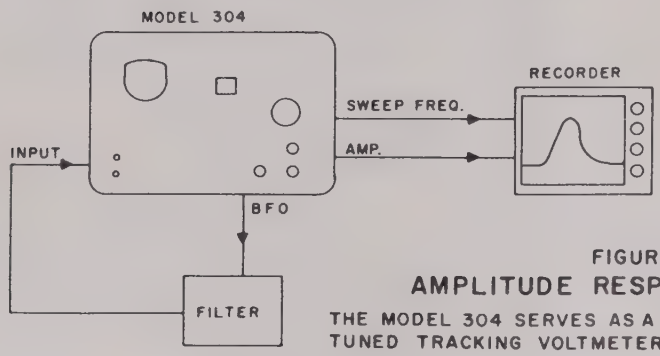


FIGURE 3
AMPLITUDE RESPONSE TESTING
THE MODEL 304 SERVES AS A SWEEPING OSCILLATOR AND TUNED TRACKING VOLTMETER.

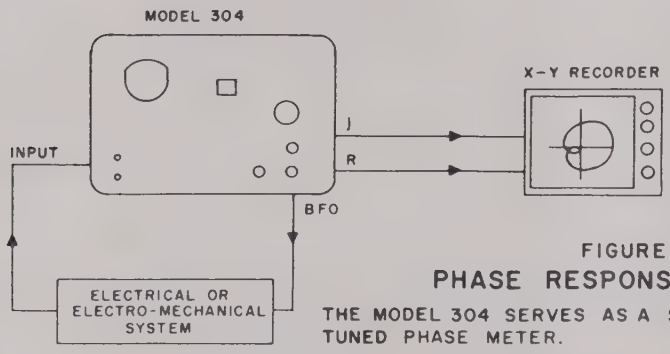


FIGURE 4
PHASE RESPONSE TESTING
THE MODEL 304 SERVES AS A SWEEPING OSCILLATOR AND TUNED PHASE METER.

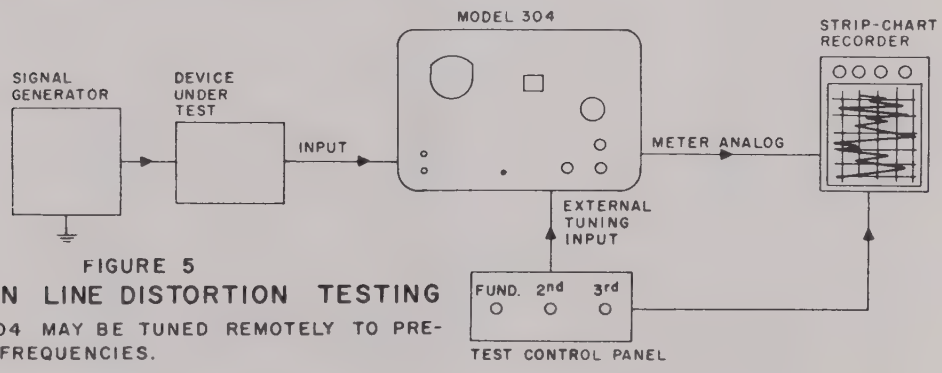


FIGURE 5
PRODUCTION LINE DISTORTION TESTING
THE MODEL 304 MAY BE TUNED REMOTELY TO PRE-PROGRAMMED FREQUENCIES.

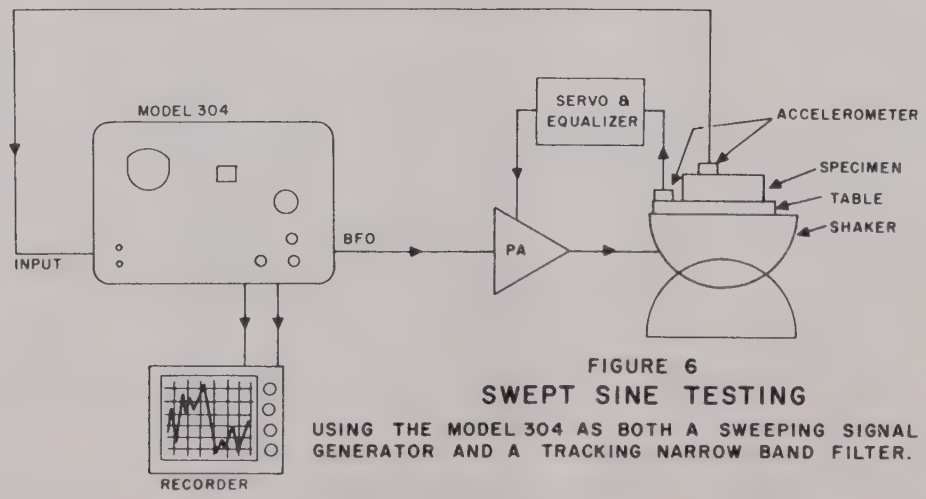


FIGURE 6
SWEPT SINE TESTING
USING THE MODEL 304 AS BOTH A SWEEPING SIGNAL GENERATOR AND A TRACKING NARROW BAND FILTER.

the resistor divider network R311 and R313. The diode string at the input of the preamplifier is for protection of the input due to transient overloads, thus allowing the transistor to be clamped either to ground or to the +15 Volt Supply. A five element maximally flat low pass filter having a cutoff frequency of slightly above 5 Kc is of straightforward design. The switch, S302, enables the operator to use the unit in either a normal mode of operation or by switching out the low pass filter when making a phase measurement.

4. POST AMPLIFIER, IST MODULATOR: SCHEMATIC T-4404 – The post amplifier is similar to the preamplifier in that it consists of a three transistor amplifier having as gain determinants R405 and R406. Q404 serves as a modulator driver and squares the signal from the variable oscillator to drive the base of the modulator transistor, Q405, thus the sum and difference signals of the variable oscillator and the incoming signal are applied to the 10 Kc bandpass filter following the circuit. In order to reject the incoming signal, a portion of the output of the post amplifier is applied 180° out of phase with the 10 Kc bandpass filter giving a high rejection to any signal in the frequency range of the 10 Kc bandpass filter.

5. 10 KC BANDPASS FILTER, ATTENUATOR, AND 1ST I.F. AMPLIFIER: SCHEMATIC T-4405 The bandpass filter consists of a three section maximally flat design having transformer input and output coupling to eliminate ground currents. The 1st I.F. Amplifier consists of two voltage gain stages and a push-pull output pair as drivers for the 2nd Modulator. CR501 and CR502 are temperature compensated diodes so that a nominal drain current is maintained in Q503 and Q504.

6. 2ND MODULATOR: SCHEMATIC T-4406 The two 2nd Modulators are driven from a +45° and a −45° phase shift 10 Kc signal. The modulators consist of a complementary pair having a single ended drive from the 10 Kc oscillator. The output of each modulator is taken from the center tap of the signal transformer.

7. VARIABLE BANDWIDTH FILTER SECTIONS 1 AND 2: SCHEMATIC T-4407 – This portion of the variable bandwidth filter is an active two section RC filter having feedback applied through C701, C702, or C703. The frequency determinants are the capacitors selected by S701. To obtain maximum DC stability in the circuitry an amplifier consisting of three differential pairs is used. The balance of the input differential pair is quite critical.

8. VARIABLE BANDWIDTH FILTER SECTIONS 3 AND 4: SCHEMATIC T-4408 – Sections 3 and 4 of the variable bandwidth filter are similar to sections 1 and 2. However, since there is gain preceding the circuitry the requirements of DC stability and balance are not critical. The outputs of Channel R and Channel j are fed to both the choppers and to their respective phase output connections on J801.

9. SUMMING CIRCUIT AND ATTENUATOR: SCHEMATIC T-4409 – The purpose of the summing circuit is to add the chopped signals from Channel R and Channel j in a linear fashion. These signals are summed using Q901 and Q902 as grounded base isolation amplifiers. The output is filtered by a tank circuit in the collectors.

10. METERING CIRCUIT: SCHEMATIC T-4410 Rectification of the 10 Kc carrier is accomplished by CR1002 and CR1001 contained in the feedback loop of the amplifier consisting of Q1001 and Q1002. The DC output is then filtered using selectable time constants obtained by adding series resistors for charging C1006. An impedance converter consisting of two differential pairs and a voltage amplifier Q1007 converts the high impedance at the output of the rectification circuit to a signal capable of driving the front panel meter and the analog output.

11. IMPEDANCE CONVERTER AND VARIABLE OSCILLATOR: SCHEMATIC T-4411 – The purpose of the impedance converter is to convert the DC voltage obtained from the tuning pot, R1101, to a low impedance output for driving the voltage controlled variable oscillator. Q1101 is a current generator for driving R1101 and is temperature compensated with R1103. Q1102 and Q1103 are differential and drive the output transistor, Q1104, of the impedance converter. R1109 serves as a balance adjustment for the converter and R1112 is part of the gain determining network. The variable oscillator consists of a multivibrator using Q1106 and Q1107 as the switching transistors. Q1105 and Q1108 are current generators which determine the operating frequency of the multivibrator. A front panel control, R1130 adjusts the frequency zero.

12. SWEEP GENERATOR: SCHEMATIC T-4412 The sweep generator consists of a constant current supply which charges a 270 microfarad capacitor, C1303, located on Board #3920, and attached to the base of Q1201. The two differential pairs consisting of Q1201, Q1204, Q1202 and Q1203 and the output transistor, Q1205, form a unity gain amplifier, and a constant voltage in excess of this output is obtained by passing a constant current from Q1208 through R1222. Since this voltage is always a constant above that of the output of the amplifier, or the condenser, C1303, a constant charging current is obtained by selection of R1207, R1208, or R1209. When the voltage at the output of the unity gain amplifier reaches that at the base of Q1207, the differential pair consisting of Q1206 and Q1207 acts as an amplifier to the output of pin D(4). The magnitude of the output ramp is selected by S1202. Q1209 provides a current buckout for the constant current generator driving the frequency control pot, R1101.

13. SWEEP CONTROL CIRCUIT: SCHEMATIC T-4413 – The sweep control circuit provides a reset function by discharging C1303. The output from pin D(4) of the sweep generator causes the one-shot multivibrator consisting of Q1302 and Q1303 to flop over which triggers Q1304 and shunts C1303 for the reset Q1301 functions as a shunt to the meter circuitry during the reset period. The purpose of this is to prevent a retrace of recording equipment from appearing at the middle of the record.

14. B.F.O. AND RESTORED FREQUENCY CHANNEL: SCHEMATIC T-4414 – The 10 Kc signal either from the fixed oscillator or from the summing circuit is amplified by Q1401 and Q1402. This 10 Kc signal is transformer coupled to the two modulator transistors, Q1403 and Q1404. The bases of this complementary pair are driven from the modulator driven transistor, Q1407. The output of the modulator is passed through a low pass filter and Q1405 and Q1406 are emitter followers affording a low output impedance.

15. FIXED OSCILLATOR, MODULATOR AND CHOPPER DRIVERS: SCHEMATIC T-4415 – The fixed 10 Kc oscillator is a simple two transistor LC oscillator. Its output is fed into phase shifting networks for driving the 2nd Modulator drivers and the BFO circuitry. Q1505 and Q1507 form a Schmidt trigger circuit which in turn drives the -45° channel of the low pass filter and Q1511 the chopper at the output of that filter section. The lower portion of the driver circuitry performs the identical function for the $+45^\circ$ channel.

MAINTENANCE AND CALIBRATION

A. GENERAL

The components and transistors in the Model 304 are conservatively rated and should provide long and trouble free service. If, however, the instrument has been damaged and recalibration or alignment is required, the following instructions should be followed explicitly, or the instrument returned to the factory. Instructions are given on the Warranty page for the procedure to be followed should it be desired to return the instrument for any reason.

Although the Model 304 is a complex instrument, trouble shooting can readily be done in sections as indicated in the Block Diagram.

Do not change any adjustments without a thorough knowledge of the circuit and the functions of the adjustment.

Standard transistor servicing care should be used throughout. Transistors can be easily damaged with large transient voltages. Therefore, take great care not to short any terminals when making measurements on the printed-circuit boards.

In soldering to the printed-circuit boards, have the iron only hot enough to make a rapid clean solder joint. DO NOT use a solder gun. DO NOT apply any force that would tend to push the copper away from the board.

B. REMOVAL FROM CASE

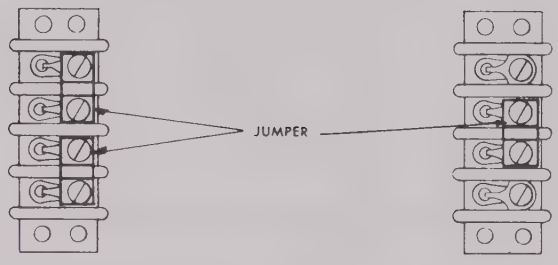
1. Remove the four screws from the rear of the case.
2. Slide the instrument gently out of the front of the case.

C. CHANGING INPUT VOLTAGE

This instrument has been designed to operate from a 117 V.A.C. or a 234 V.A.C. power source. The plate on the rear of the instrument near the power cord indicates the voltage and frequency at which the instrument should be operated.

Should it be desired to change the input voltage,

1. Remove the instrument from the case.
2. Change the transformer primary connections by moving the jumpers on the 4 terminal barrier strip located near the power cord (See Figure 7).



For 117 V.A.C. operation For 234 V.A.C. operation

FIGURE 7. INPUT VOLTAGE BARRIER STRIP

3. Change the fuse. For 117 V.A.C. operation, the fuse should be ¼ Amp. Slow Blow; for 234 V.A.C. operation the fuse should be 1/8 Amp. Slow Blow.
4. Reverse the plate located near the power cord to read the correct voltage.

D. CALIBRATION

1. GENERAL – The Model 304 is a precision instrument, the accuracy of which depends in large part on critically balanced DC circuitry. The circuits in turn are designed to operate over a moderate temperature range. However, the instrument cannot cope with thermal shocks or transients which cause differential temperatures to occur between individual components. The closed-box environment provided by the Model 304's case affords its circuits both thermal-transient and electrostatic shielding, thereby resulting in more stable operation. During calibration similar protection may be required in the interest of accuracy. It is also recommended that the new "extender boards" supplied with each instrument be used in the case of those adjustments which cannot be made without removing the circuit board. If a circuit board must be temporarily removed from its socket, or if the unit is momentarily turned off – be sure to allow the instrument time to restabilize before making further adjustments.

Following is an outline of the set-up procedure. It is important that the adjustments be made in the prescribed order, in that some of them depend upon completion of the previous ones.

CAUTION

Included in this procedure are a number of adjustments which require the actual selection and installation of components. These particular adjustments are intended to be made ONLY on new assemblies or those which have received catastrophic damage necessitating a major overhaul. These components are denoted on the schematic drawings as "factory adjustments" (f.a.) and are NOT to be considered as routine adjustments.

2. ADJUSTMENT PROCEDURE OUTLINE

a. Frequency Determinants
   (1) Power Supplies
   (2) Impedance Converter
   (3) Variable Oscillator
   (4) Fixed Oscillator
   (5) Sweep Circuits

b. Signal Channel
   (1) Pre-Ampl. and Post-Ampl.
   (2) Meter zero adjustments.
   (3) R/j channel balance.
   (4) Calibrate the meter circuit.
   (5) Balance the 1st Modulator.
   (6) Adjust system gain.
   (7) Check 2nd Modulator performance.

c. Peripheral circuits checks and adjustments.
   (1) BFO and restored frequency channel.
   (2) Check amplitude response.
   (3) Phase calibration.

3. EQUIPMENT REQUIRED:

VOM	Avometer or equivalent.
DVM	Calibration Standards DC-200AR or equivalent.
VTVM	H.P. type 400-D or equivalent.
OSCILLATOR	H.P. type 200-CD or equivalent.
FREQUENCY COUNTER	CMC type 201-A or equivalent.
OSCILLOSCOPE	Tektronix type 503 or equivalent.
RECORDER	Varian type G-11A or equivalent.

4. CALIBRATION OF FREQUENCY DETERMINANTS

a. **Power Supplies** – Assy. #4391 & #4392. With an ungrounded DVM, monitor the +15.V buss on connector board Assy #4427.
   (1) Select R-106 such that $+E_o$ = 15.V, ±50 MV.
   (2) Similarly select R-206 so that $-E_o$ = 15.V, ±50 MV.
   (3) Allow sufficient time for the power supplies to re-stabilize before going on to the next adjustment.

b. **Impedance Converter** – Assy. #4390
   (1) Set frequency dial to 000, connect DVM to frequency analog (Pin 7 of J-801) and adjust the analog zero control R-1109 for an output of 0.000 volts, ±3 MV.
   (2) Advance frequency dial to 5000. and adjust R-1104 for an output of 5.000 V., ±10 MV.
      (a) It may be necessary to pad R-1106 to bring R-1104 within operating range. If this is the case, use a high quality resistor such as a metal film, 150 ppm type.
   (3) DO NOT adjust R-1112 at this time.

c. **Variable Oscillator** – Assy #4389
   (1) Set frequency dial to 000 and the FREQUENCY ZERO pot to the middle of its range.
   (2) Monitor the variable oscillator output at test-point one (TP-1) with a counter.
      (a) Frequency , should be between 10,100 cps and 10,400 cps.
   (3) Shunt R-1125A with a quality resistor that will lower the frequency to 10,000 ±20 cps. (If oscillator fails to restart, flick power switch momentarily off, then back on.)
   (4) Advance dial to 5000. and adjust R-1112 on Assy. #4390 for a frequency of 15,000. ±10 cps.
      (a) It may be necessary to pad either R-1113 or R-1114. (Use a quality resistor.

d. **Fixed Oscillator** – Assy #4384
   (1) Set R-1511 to the middle of its range and with the counter connected to test point two (TP-2) adjust the variable capacitor for a frequency of 10,000. ±3 cps.

e. **Sweep Circuit** – Assy #4394 and #4395
   (1) Set the SWEEP controls as follows:
      (a) Sweep time .....OFF
      (b) Sweep width ....5 KC
      (c) Sweep mode ....RESET
      (d) Dial 000

(2) Connect a counter to TP-1 and note the frequency. (Approx. 10 KC)
(3) Adjust R-1212 on Assy #4395 such that the frequency does not change as the sweep time switch is operated between OFF and SLOW.
(4) Now operate the sweep width control to 1 KC and similarly adjust R-1218 such that the frequency at TP-1 does not change as the sweep time control is switched from OFF to SLOW.
(5) Set the SWEEP controls to FAST, SINGLE and 5KC. Upon completion of one scan, (approx. 18 sec.), the frequency at TP-1 should be 15 KC, ±100 cps. Similarly check the remaining sweep wdiths to the following accuracies:
   (a) 1000, ±30 cps.
   (b) 500, ±15 cps.
   (c) 100, ±3 cps.
   (d) 50, ±1.5 cps.
   (Re-adjust R-1212 and/or R-1218 if necessary.)
(6) Adjust the sweep time as follows:
   (a) Connect a strip-chart recorder to the SWEEP ANALOG jack with its sensitivity set to approximately 5 volts full scale and a chart speed of about 15 in./hr.
   (b) Set the sweep time control to SLOW.
   (c) Reset the sweep and then operate the mode switch to SINGLE.
   (d) Shunt R-1223 on Assy #4395 as required to shorten the time required for one scan to 30 min., ±10%.

NOTES:

1. Since the sweep circuit generates a very linear ramp voltage (0 to + 5V) the total ramp time may be extrapolated by measuring only a portion of the total sweep voltage, perhaps 1 or 2 volts.
2. It is recommended that the overall calibration of the sweep circuit be re-checked before continuing.

5. CALIBRATION OF THE SIGNAL CHANNEL

a. **Pre-amp. and post-amp.** – Assy. #4396
   (1) With the positive lead of a DC voltmeter on pin J(8) and the METER MULTIPLIER switch set to X100, select R-312 for a reading of zero volts +50 MV., –0 MV.
   (2) Change the METER MULTIPLIER to the X .01 position and select R-306B such that the change in DC offset voltage at pin J(8) does not exceed ±50.MV as the switch is operated between the X.01 and X100 ranges.
   (3) Now connect the positive lead of the voltmeter to the positive end of C-401 and with the METER MULTIPLIER on the X1. range and the VARIABLE GAIN control full clockwise (calibrated), select R-407 for a reading of +2.5V, ±500MV.

b. **Meter Zero.** In order to obtain both the required range and resolution of the meter zero controls it is necessary to have both coarse and fine adjustments for each channel. They are set up as follows:
   (1) Set both of the METER ZERO controls to mid range.
   (2) If the meter is reading on scale proceed to step (4); if not, connect a DC voltmeter to pin #6 of J-801 and adjust channel "R", coarse meter zero control R-719 on connector board, assy #4378, as nearly to zero volts as is possible.
   (3) Similarly, connect the VM to pin #5 of J801 and adjust the "j" channel zero pot.
   (4) The meter pointer should be reading on scale such that nearly a perfect null may be obtained by alternate adjustment of the METER ZERO controls.

c. **R/j Channel Balance.** When the gain and phase response of the R and j channels is properly adjusted, meter ripple can be held as low as ±1%. Balance the two channels as follows:
   (1) With the BANDWIDTH set to 100 and the MILLIVOLTS FULL SCALE switch on 1000, tune the instrument to a full scale 1 Kc signal. Maintain tuning to within ±10 cps of incoming signal while making the following adjustments:

(a) Connect a scope to pin L(10) of Assy. #4380. With the scope's sensitivity and sweep speed set for approximately 100 Mv/cm and 0.1 sec, alternately adjust R-901 and R-1511 (on Assy. #4384) for the smallest possible low-frequency amplitude fluctuations. Make sure that the meter is properly zeroed when making these adjustments.

d. **Meter Circuit** - Assy#4381
   (1) Connect a DC voltmeter (positive lead) to pin #2, J-801.
   (2) Tune the Model 304 to a full scale signal and pad R-1019 such that the meter reads 10.V, ±2%.

e. **1st Modulator** - Assy#4388 This circuit must be balanced with respect to an incoming signal. Do this as follows:
   (1) Set the PHASE/NORMAL switch to PHASE.
   (2) With the METER MULTIPLIER set to X1. and the MILLIVOLTS FULL SCALE switch to 1000, tune to a 1000 cycle full scale signal.
   (3) Remove the 1Kc signal and apply a 10. Kc, ±30 cps, signal of the same amplitude to the input and tune the Model 304 to 2500 cps.
   (4) Increase the Model 304's sensitivity as required while alternately adjusting R-418 and C-403 on Assy. #4388 for the best possible null.
      (a) This should be at least −60 db below the 1 Kc reading.

f. **Calibrate the gain** of the overall system by applying a 1 Kc signal of known amplitude to the input and adjusting R-907, the Gain Cal. pot located at the rear of the instrument, for the correct meter reading.

g. **Check 2nd Modulator** - Assy #4386 offset voltage as a function of signal level. Set the controls as follows:
   (1) BANDWIDTH to 10 cps
   (2) MILLIVOLTS FULL SCALE to 3
   (3) METER MULTIPLIER to X1.
   (4) VARIABLE GAIN to full clockwise (CALIBRATED)
   (5) FREQUENCY Dial to 500
   (6) SWEEP, OFF

   Carefully zero meter and then apply a one volt RMS, 1100 cps signal to the input. Note meter deflection; if it exceeds two divisions on the 0-3 scale determine which modulator is at fault (channel R or j) and replace transistors with a suitable selected pair.

6. PERIPHERAL CIRCUITS, CHECKS AND ADJUSTMENTS

a **The BFO and Restored** signals are developed by largely the same circuitry – of which no calibration is required. If it is functioning properly, the BFO signal should meet the following requirements:
   (1) It shall deliver at least 1 volt RMS into a 600 ohm load.
   (2) The total full load harmonic distortion shall not exceed 2%.
   (3) The DC offset is not to exceed ±100 MV.
   (4) Frequency response shall be flat to within 2% from 1 cycle to 5 Kc.
   (5) The Restored output should be at least 0.5 Volt RMS into a 600 ohm load for a full scale meter reading.

b. **Frequency response** of the main signal channel should be checked with the PHASE/NORMAL switch in the NORMAL position and it should be flat to within 2% peak to peak.

c. **Calibrate for phase** measurement accuracy by the following procedure:
   (1) Connect the R output to the horizontal input of a Tektronix type 503 scope.
   (2) Connect the j output to the vertical input.
   (3) Install special graticule (Quan Tech #4628) on scope and with both inputs to the scope grounded, set scope beam to the apex of the intersecting lines in the upper left quadrant of screen.
   (4) Set both the vertical and horizontal inputs to a sensitivity of about 100 MV/cm.
   (5) Calibrate the Model 304's dial and set it to 24 cps.
   (6) Set the bandwidth to 10 cps.
   (7) Adjust the BFO to approximately 1V RMS and connect it to the INPUT terminals.
   (8) Adjust the input attenuators and meter sensitivity such that the meter reads full scale.

The scope beam should have moved from the upper left, to the upper right side of the screen exactly parallel to the horizontal (R) axis. If it did not do so, but instead formed some angle with the line as it traversed the scope face, adjust R-1514 (on the connector board Assy #4383) such that it does. This may readily be checked by adjusting the BFO level control from maximum to minimum and back to maximum again while viewing the scope.

The system is now calibrated such that with no external phase shift between the BFO output jack and the analyzer input terminals, the scope indicates no phase angle between the beam and the R axis. Assure the correct performance of the system by installing in this signal loop a known phase shift to see if a proportional phase angle is indicated on the scope face.

(1) Connect a 10 mfd paper capacitor across the INPUT terminals and a 100 K resistor between the red input terminal and the BFO output jack. (This represents a phase shift of approximately -90°)

(2) Readjust the METER MULTIPLIER for a full scale meter reading and note the position of the scope beam. It should now be located in the lower left quadrant forming a $90^\circ \pm 5\%$ phase angle with the R axis.

A final phase accuracy test of the unit should be performed as follows:

(1) With the same test configuration, equally reduce the sensitivity of both the horizontal and vertical inputs to about 0.2 Volt/cm.

(2) With no signal input to the scope, locate the beam to the exact center of the screen.

(3) Connect the BFO directly to the analyzer input and adjust for a full scale meter reading. The beam should have moved directly to the right. Now while slowly tuning from 24 cps to 5 Kc the scope beam should linearly inscribe a clockwise arc of approximately 135° indicating a system phase shift of approximately 0.027 deg/cycle and therefore normal operation.

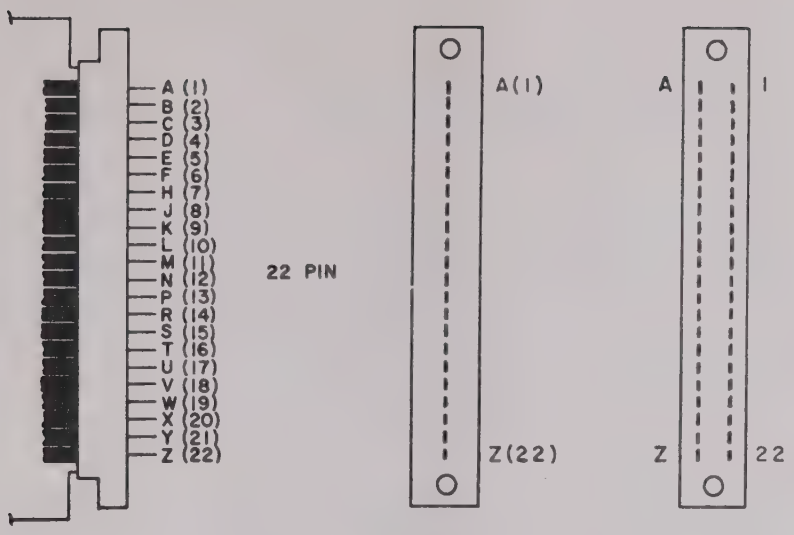


FIG. 1 PRINTED CIRCUIT BOARD LUG IDENTIFICATION

Fig. 1 illustrates the identification and orientation of a printed circuit board and connector utilizing 22 pins.

When a printed circuit board of a lesser number of pins is called for, the same designating sequence shall apply.

When a single sided copper P.C. Board is used, its pin identification shall be as shown in Fig. 1, and its schematic references shall be A(1), B(2), C(3) etc. The copper side faces the observer when viewed as shown at the left.

When using a double sided copper P.C. Board, its pin orientation shall be as shown in Fig. 1 and its schematic references shall be as follows:

a. (A), (B), (C) etc. signifies that electrical connections are made to lettered side of P.C. Board (A side).

b. (1), (2), (3) etc. signifies that electrical connections are made to numbered side of P.C. Board (1 side).

c. A(1), B(2), C(3) etc. signifies that electrical connections are made to both sides of P.C. Board simultaneously, i.e., A and 1 are schematically connected.

SEMICONDUCTOR LEGEND

Changes and improvements in the semiconductor products available for commercial use necessitate type changes from time to time. To eliminate confusion and costly paperwork, many of these changes will be covered in the following legend. The purpose of this legend is to acknowledge the fact that the type number on a semiconductor found in a piece of equipment will not necessarily correspond with the type number given on the schematic diagram.

The legend is not intended to be an interchangeability list although in many cases good quality components* within a given category may be substituted with acceptable results. Normally, replacements should be made using components having the same type number as the component being replaced.

Those components bearing an asterisk on the schematic diagram are factory selected components and should be obtained from Quan-Tech.

*It should be noted that the incoming inspection procedure followed at Quan-Tech includes noise screening on most semiconductors.

TYPE NO. ON SCHEMATIC	TYPE NO. IN EQUIPMENT
1N482A	1N648, 1N3604, 1N3605
1N703	1N748, 1N749
1N709	1N753
1N2859	1N3253, 1N3254
1N2862	1N3254
1N3253	75A4, 1N3254
1N3254	75A4
1N3604	1N3605, 1N482A, 1N648
1N3605	1N3604, 1N482A, 1N648
TIS73	TIS75
TI480	2N1613, 2N3566, 2N3643 A322, 2N929
TI494	2N1613, 2N3566, 2N3643, A322, 2N929
UC240	2N4869, 2N3819
2N270	2N3644, 2N3250, 2N3251
2N396A	2N414, 4JX1G759, 4JX1D653, 2N3644, 2N3250, 2N3251
2N414	2N396A, 4JX1G759, 4JX1D653, 2N3644, 2N3250, 2N3251
2N929	A322, A324, A642, 220N2, 2N3566, 2N3643, 2N2219

TYPE NO. ON SCHEMATIC	TYPE NO. IN EQUIPMENT
2N1304	2N1306, 2N3566, 2N3643, A322
2N1306	2N1304, 2N3566, 2N3643, A322
2N1515	2N3644, 2N3250, 2N3251
2N1613	2N3566, 2N3643, A322, 2N2219
2N2219	D16C33, 220N2, A322, A324, A642, 2N3566, 2N3643
2N2603	2N3250, 2N3251
2N3250	2N3251, 2N3644
2N3251	2N3250, 2N3644
2N3566	2N3643, A322, 2N929, 2N2219
2N3643	2N3566, 2N2219, A322, 2N929
2N3644	2N3250, 2N3251
2N3819	TIS73, TIS75, TIS59, 2N4869, UC240,
2N4869	2N3819, UC240

SCHEMATIC LEGEND

k – 1000

– Screw Driver Adjustment

– Front Panel Control

* – Factory Select

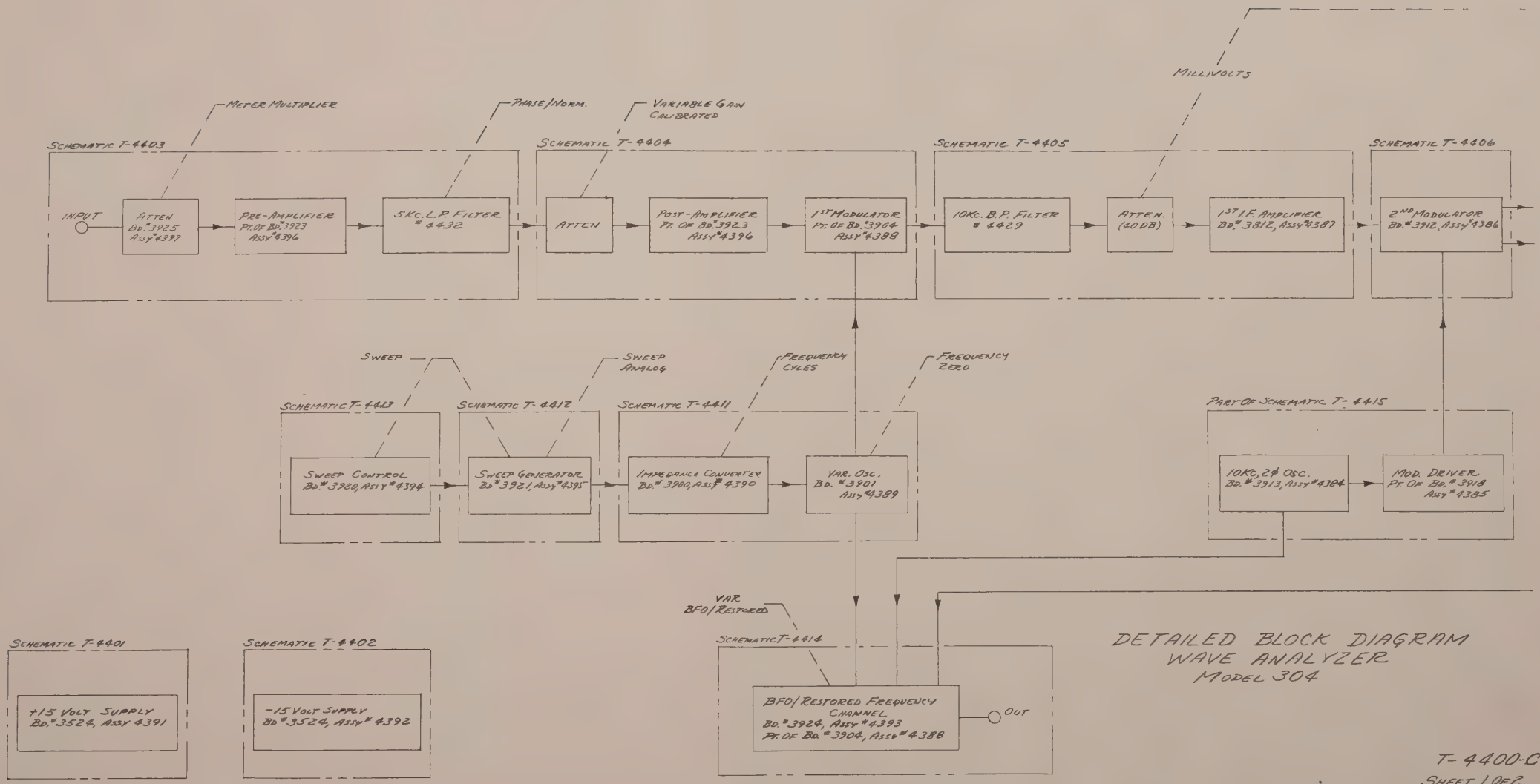
Unless Otherwise Specified:

All Resistances in Ohms

All Resistors 1/2 Watt

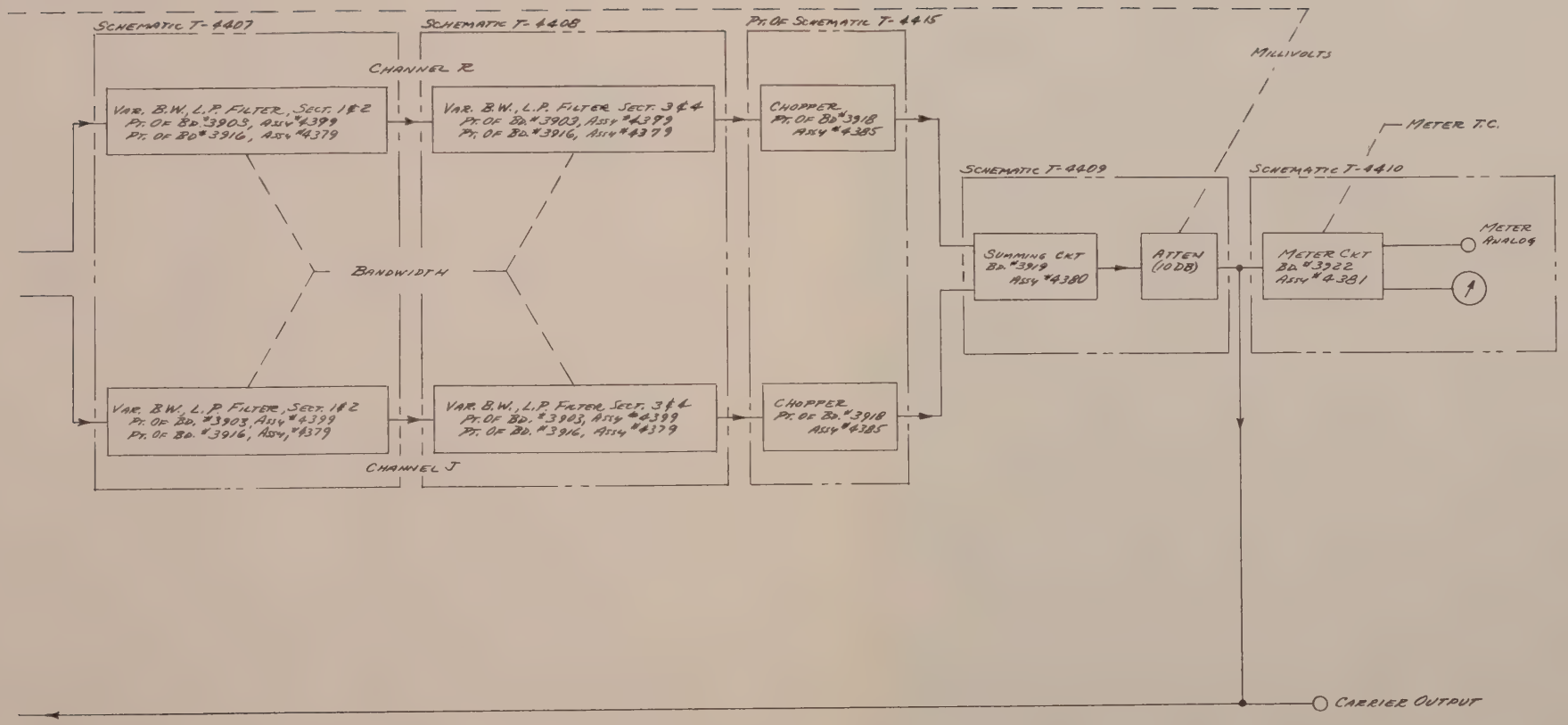
All Capacitances in Microfarads

5/21/71



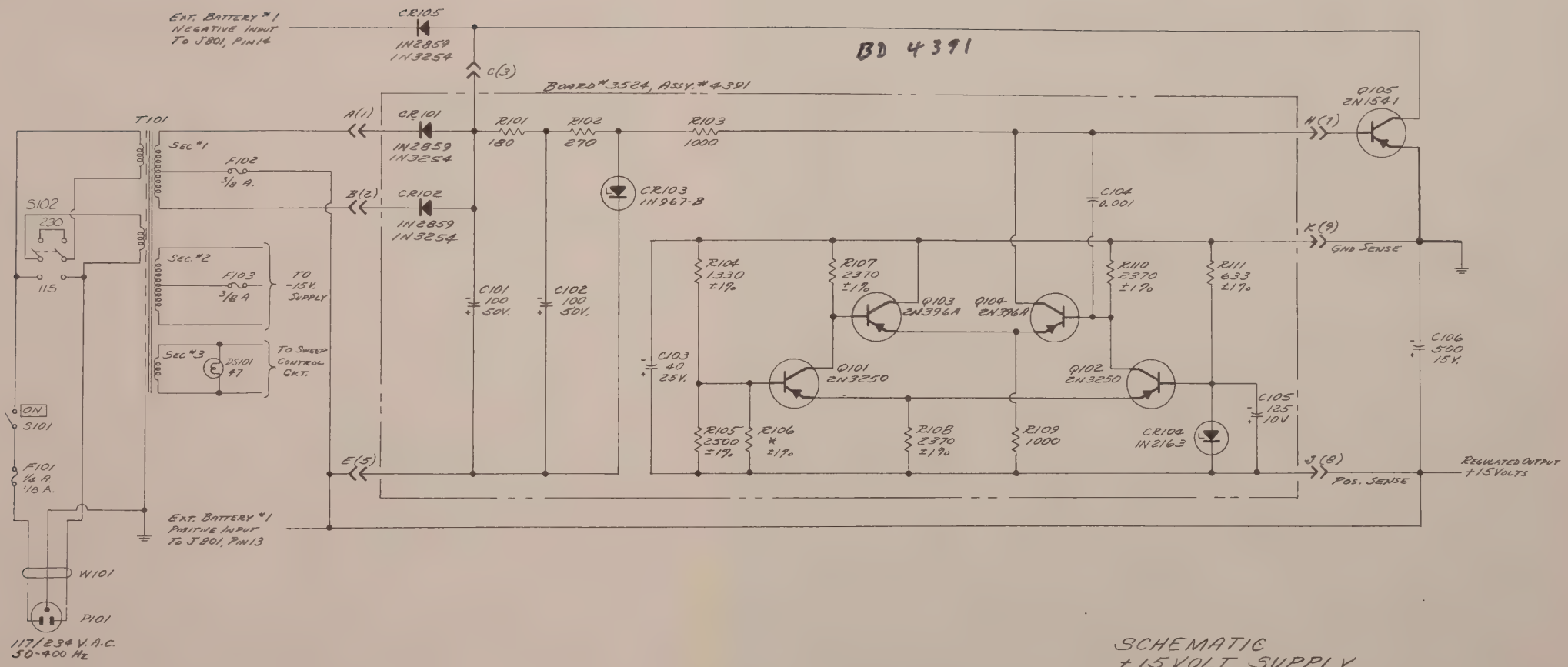
DETAILED BLOCK DIAGRAM
WAVE ANALYZER
MODEL 304

T-4400-C
SHEET 1 OF 2



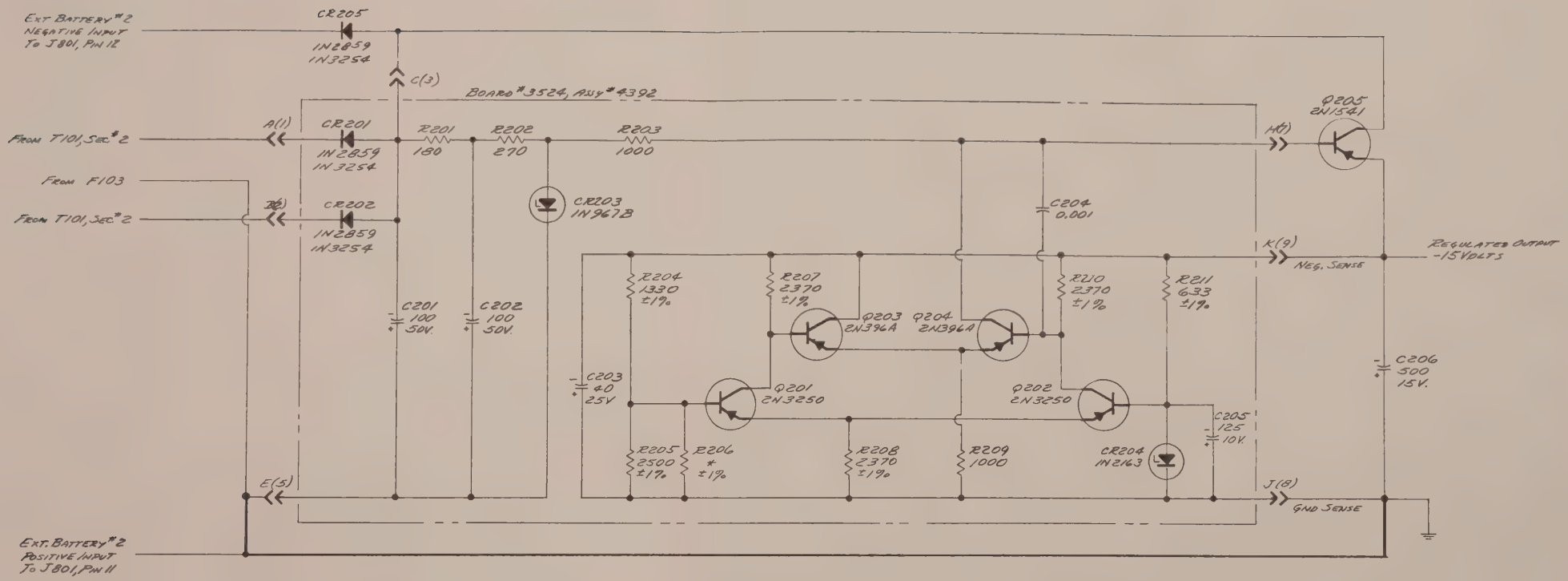
DETAILED BLOCK DIAGRAM
WAVE ANALYZER
MODEL 304

T-4400-C
SHEET 20F 2



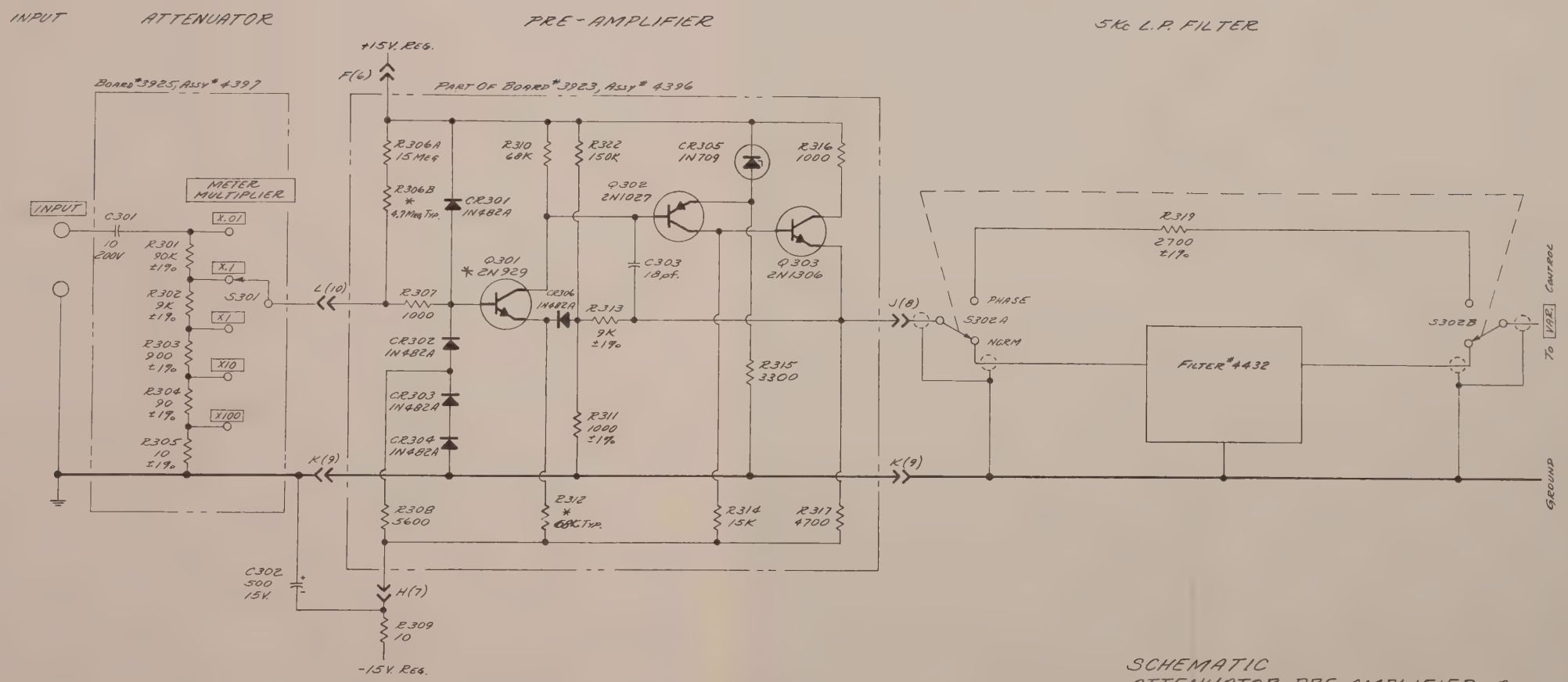
SCHEMATIC
+15 VOLT SUPPLY
MODEL 304

T-4401-F



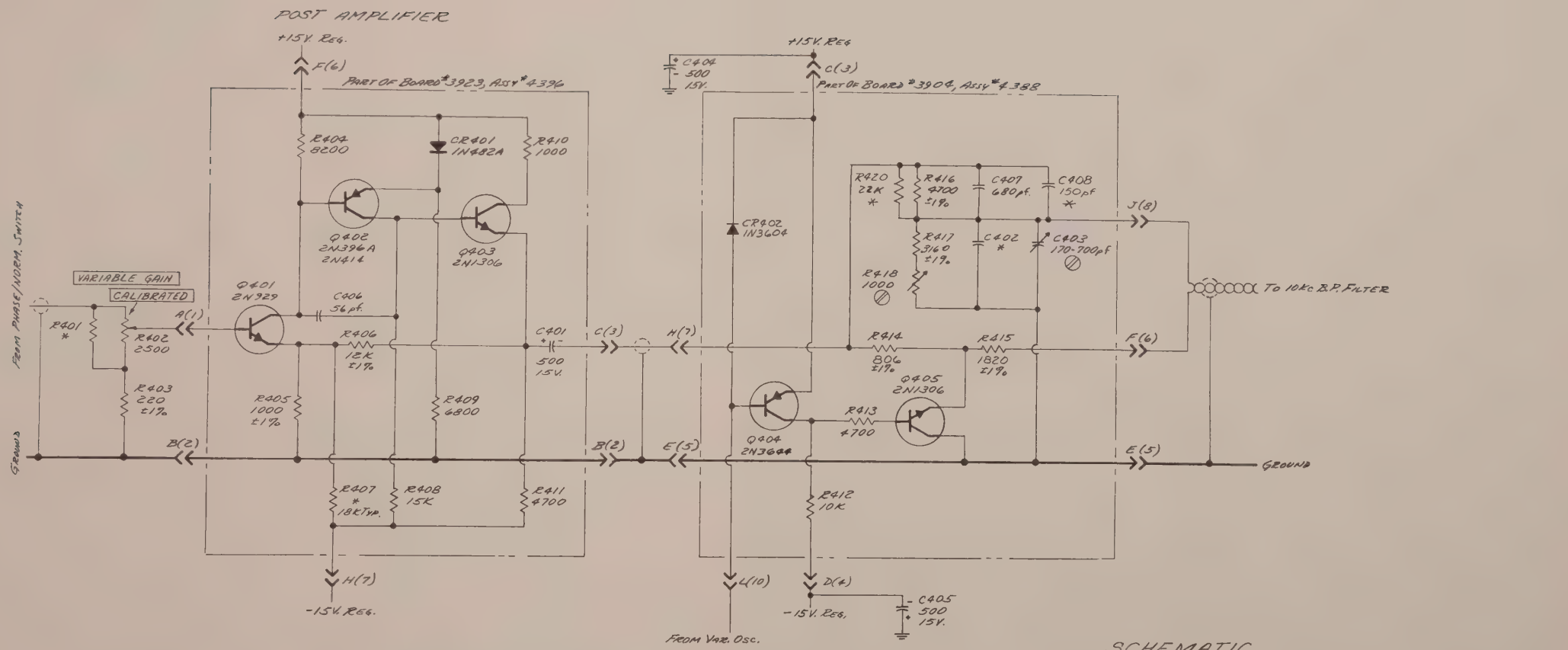
SCHEMATIC
-15 VOLT SUPPLY
MODEL 304

T-4402-D



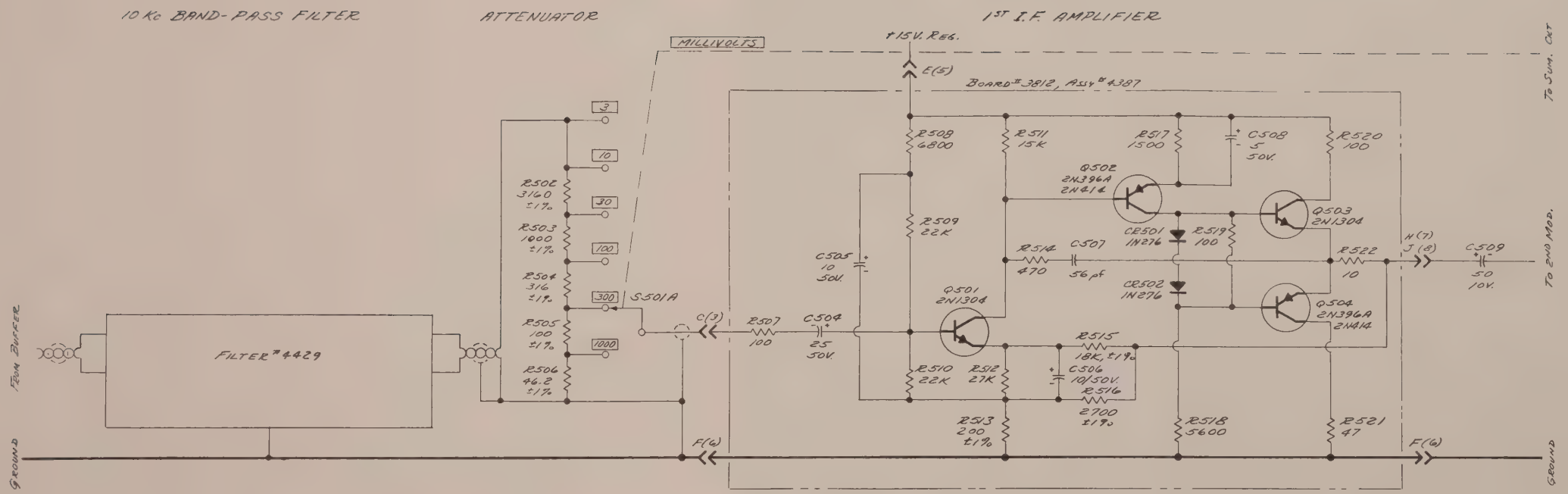
SCHEMATIC
ATTENUATOR, PRE-AMPLIFIER AND
5KC. L.P. FILTER
MODEL 304

T-4403-C



SCHEMATIC
POST AMPLIFIER, 1ST MODULATOR,
MODEL 304

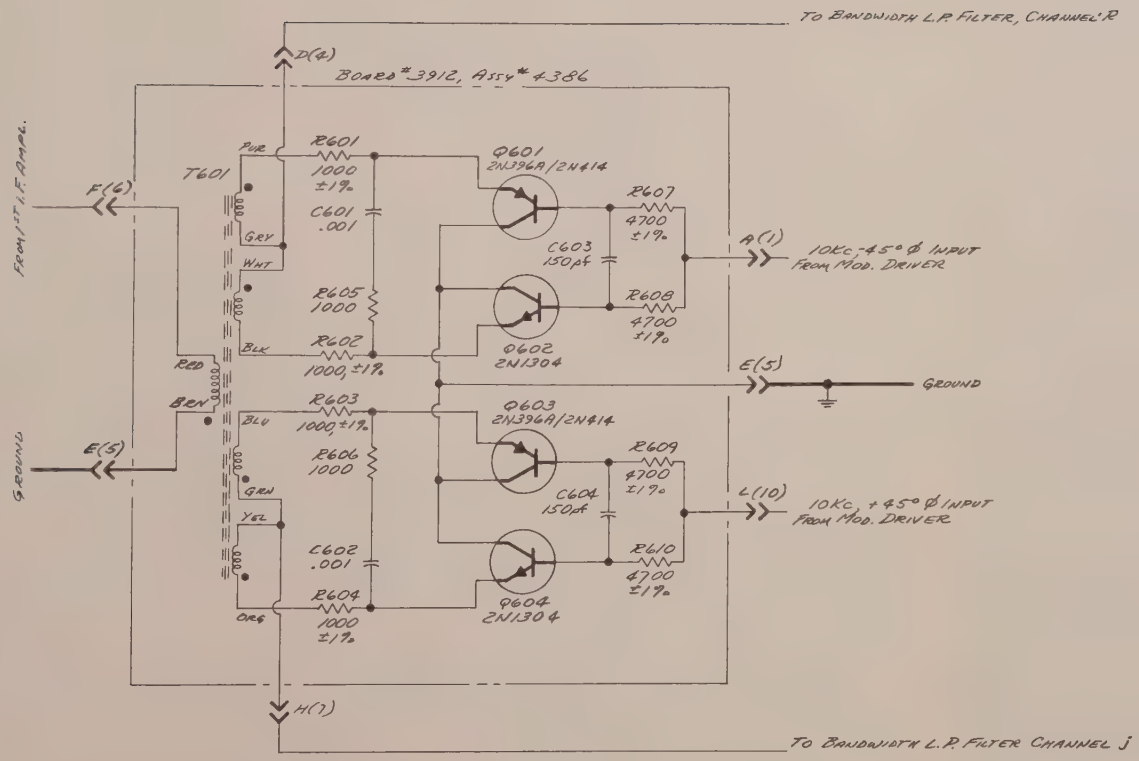
T-4404-E



SCHEMATIC
10 Kc B.P. FILTER, ATTENUATOR AND
1ST I.F. AMPLIFIER
MODEL 304

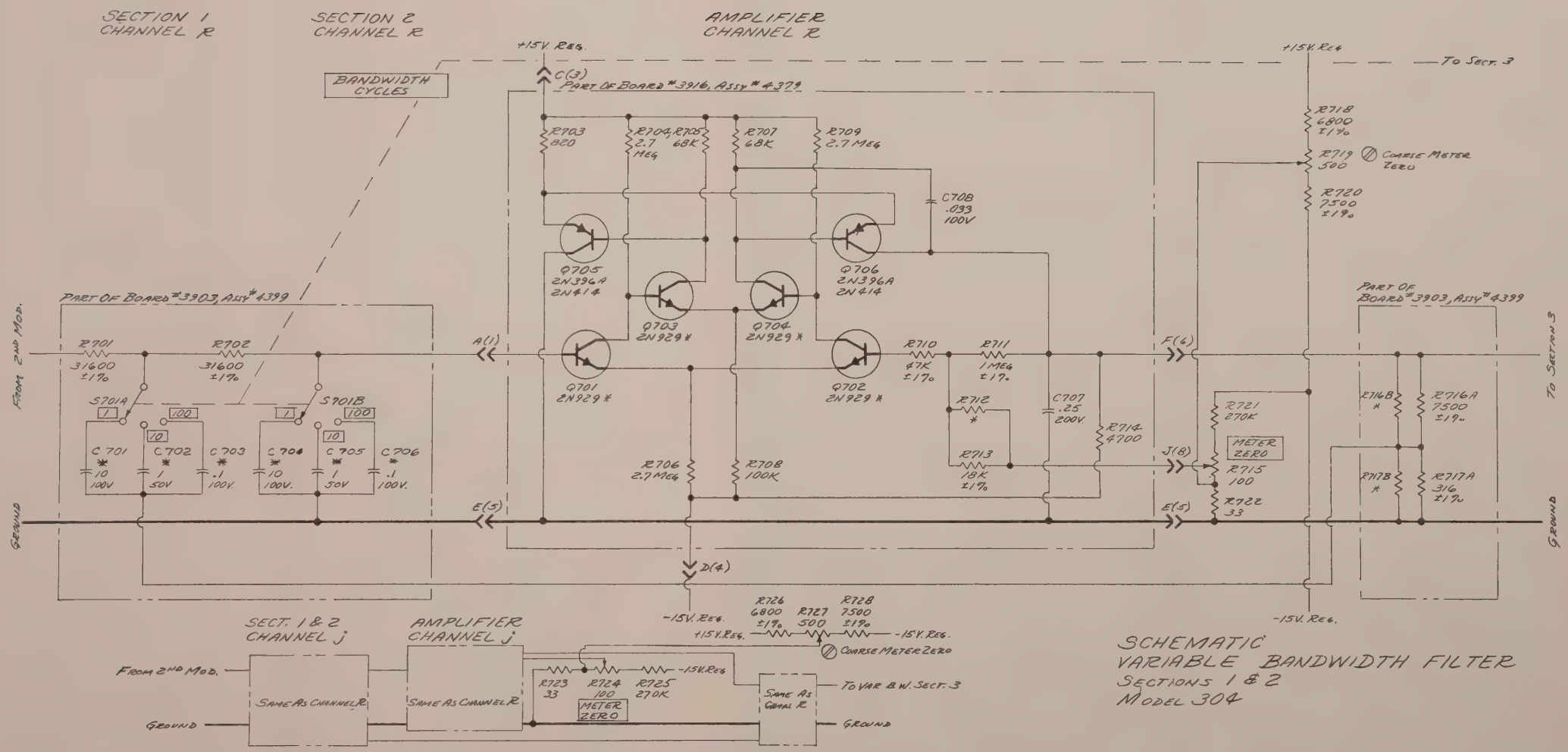
T-4405-B

2ND MODULATOR



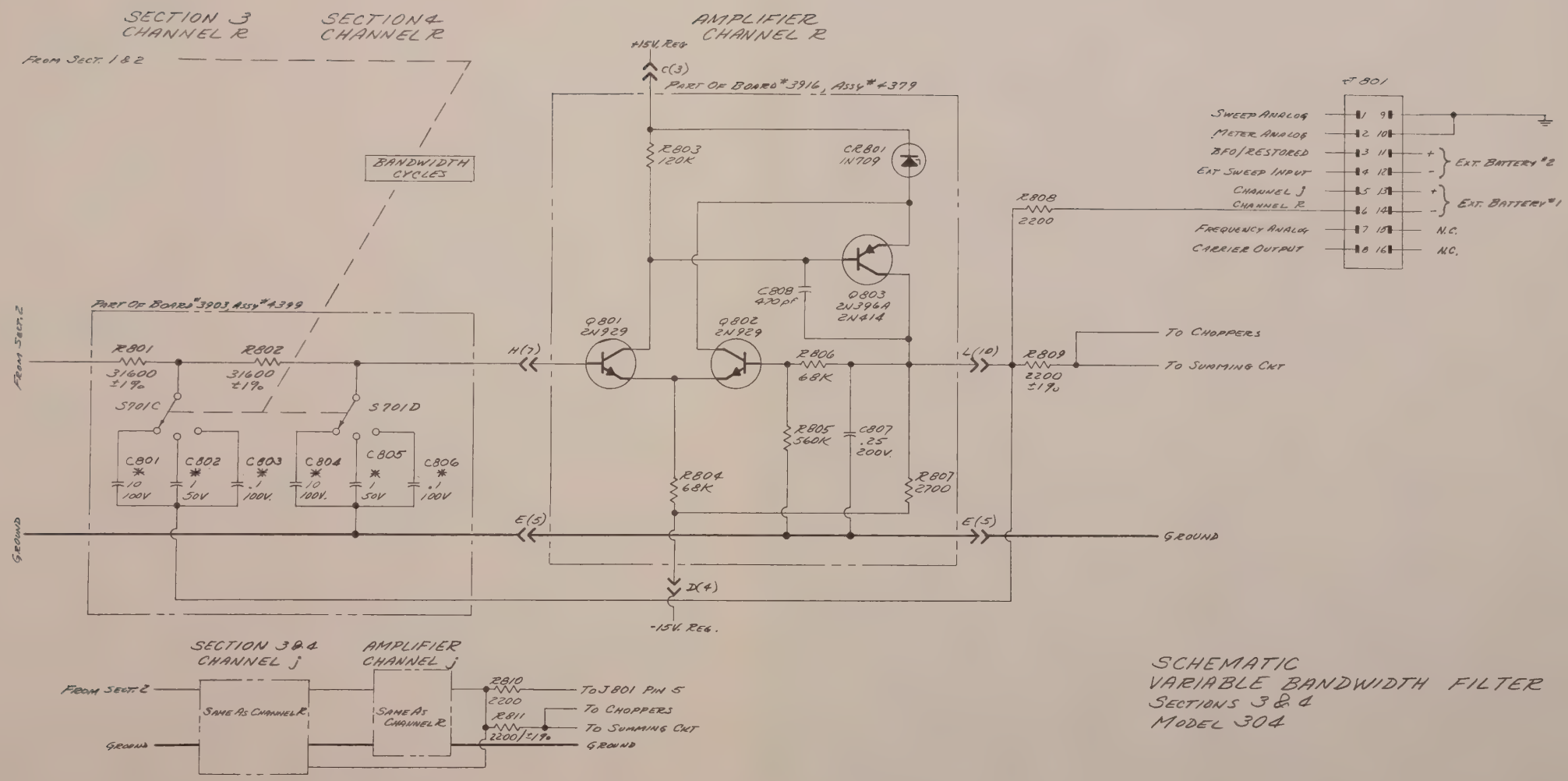
SCHEMATIC
2ND MODULATOR
MODEL 304

T-4406-C



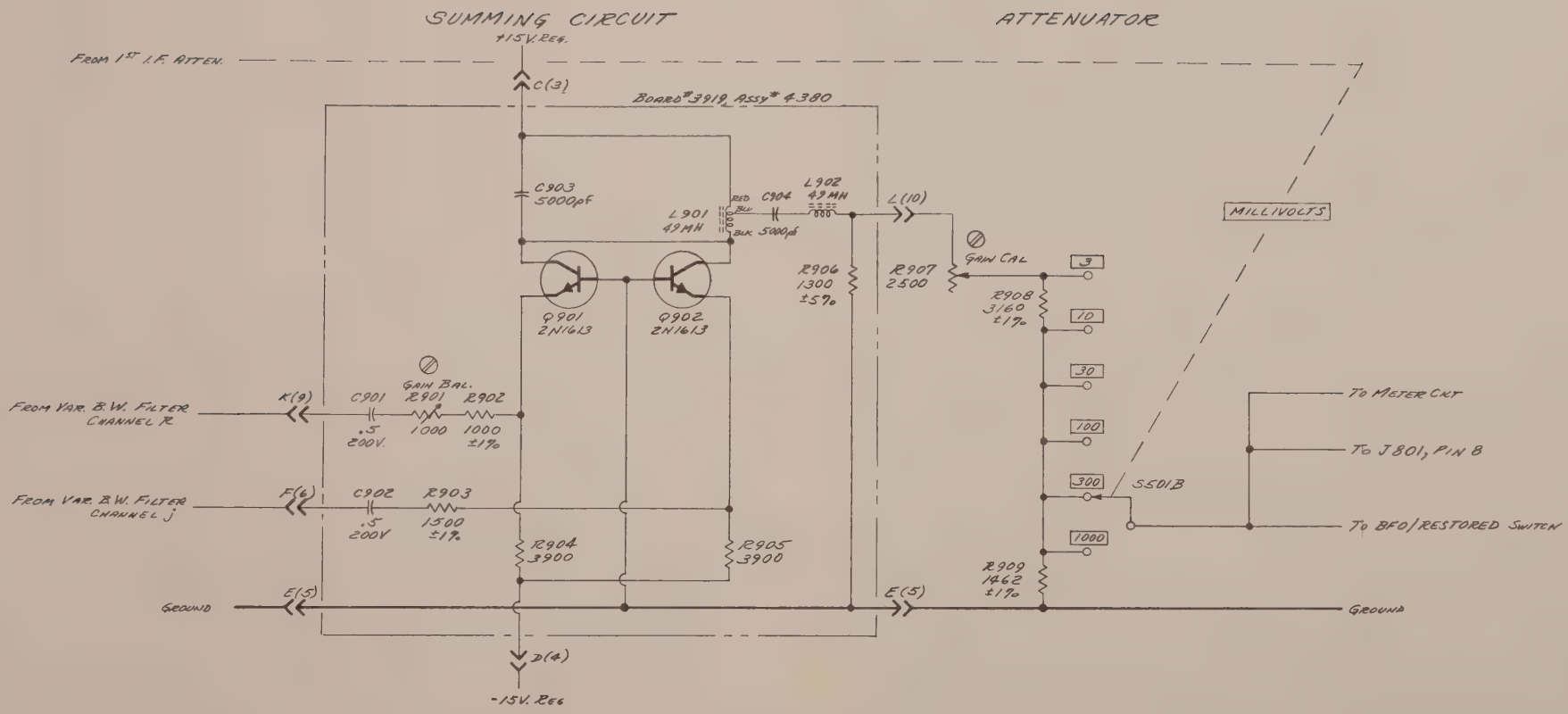
SCHEMATIC
VARIABLE BANDWIDTH FILTER
SECTIONS 1 & 2
MODEL 304

T-4407-D



SCHEMATIC
VARIABLE BANDWIDTH FILTER
SECTIONS 3 & 4
MODEL 304

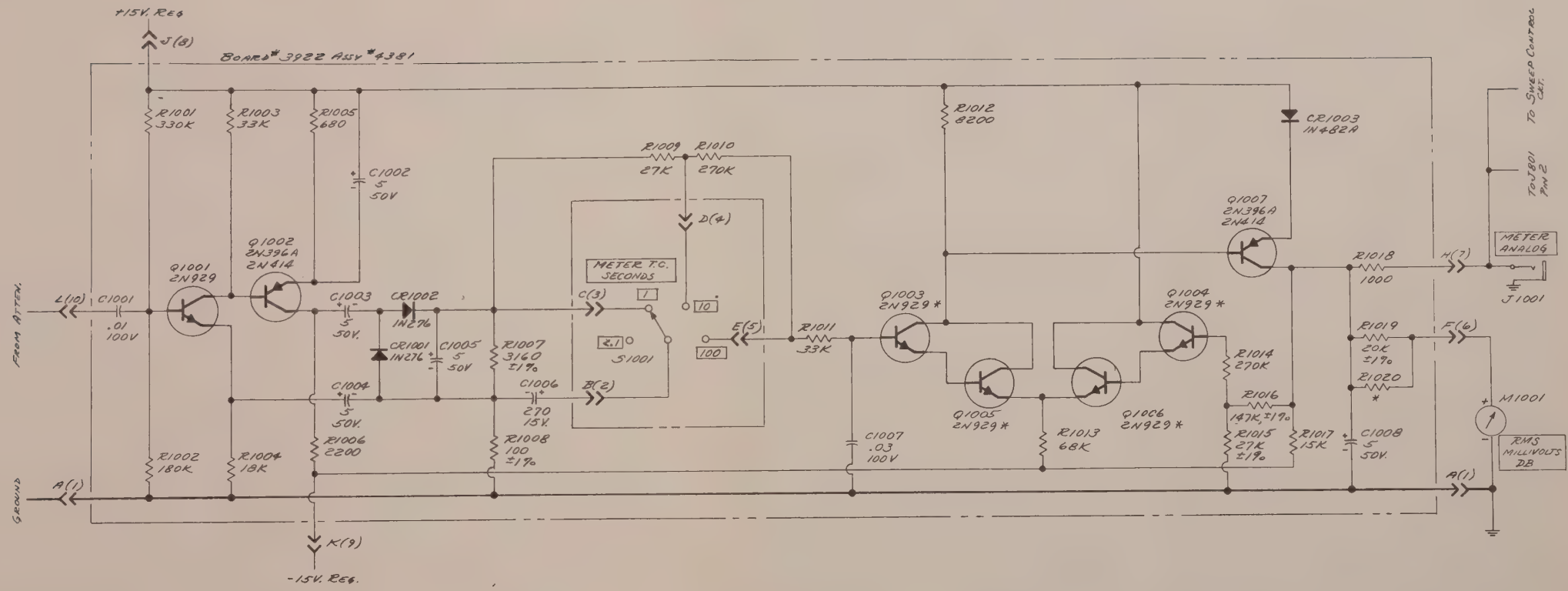
T-4408-E



SCHEMATIC
SUMMING CIRCUIT AND ATTENUATOR
MODEL 304

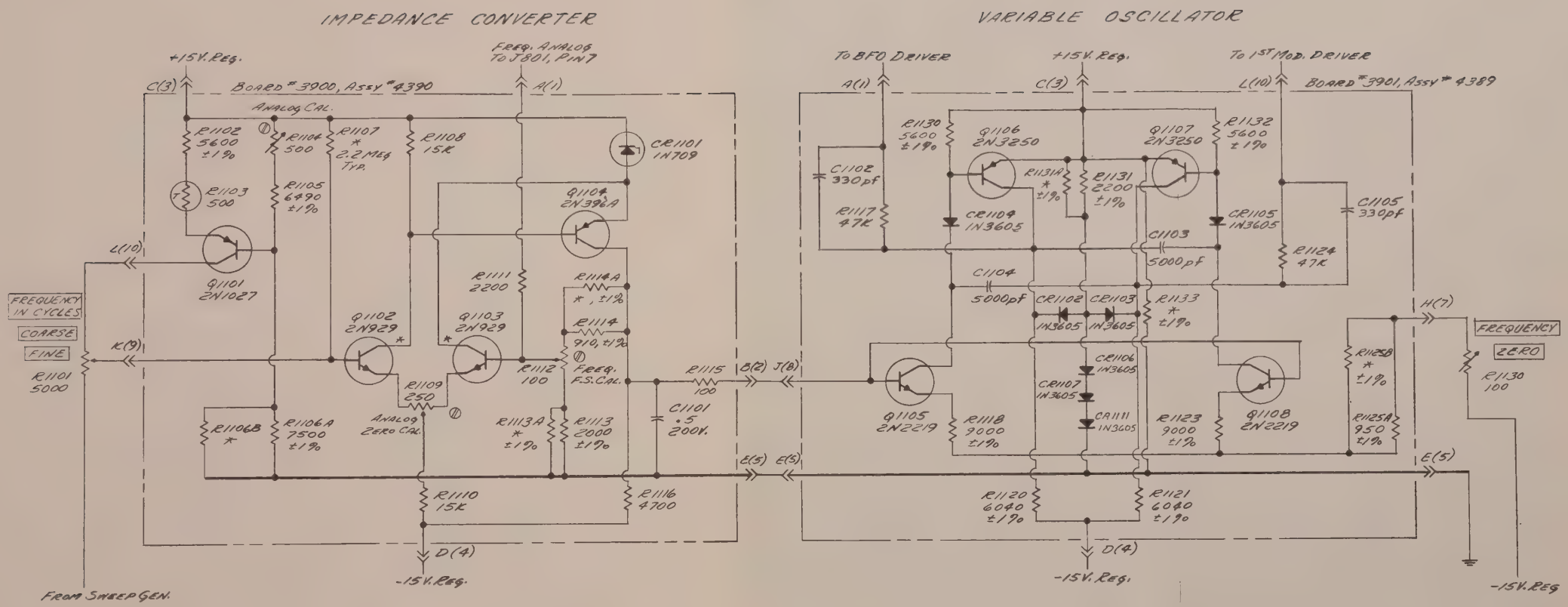
T-4409-C

METERING CIRCUIT



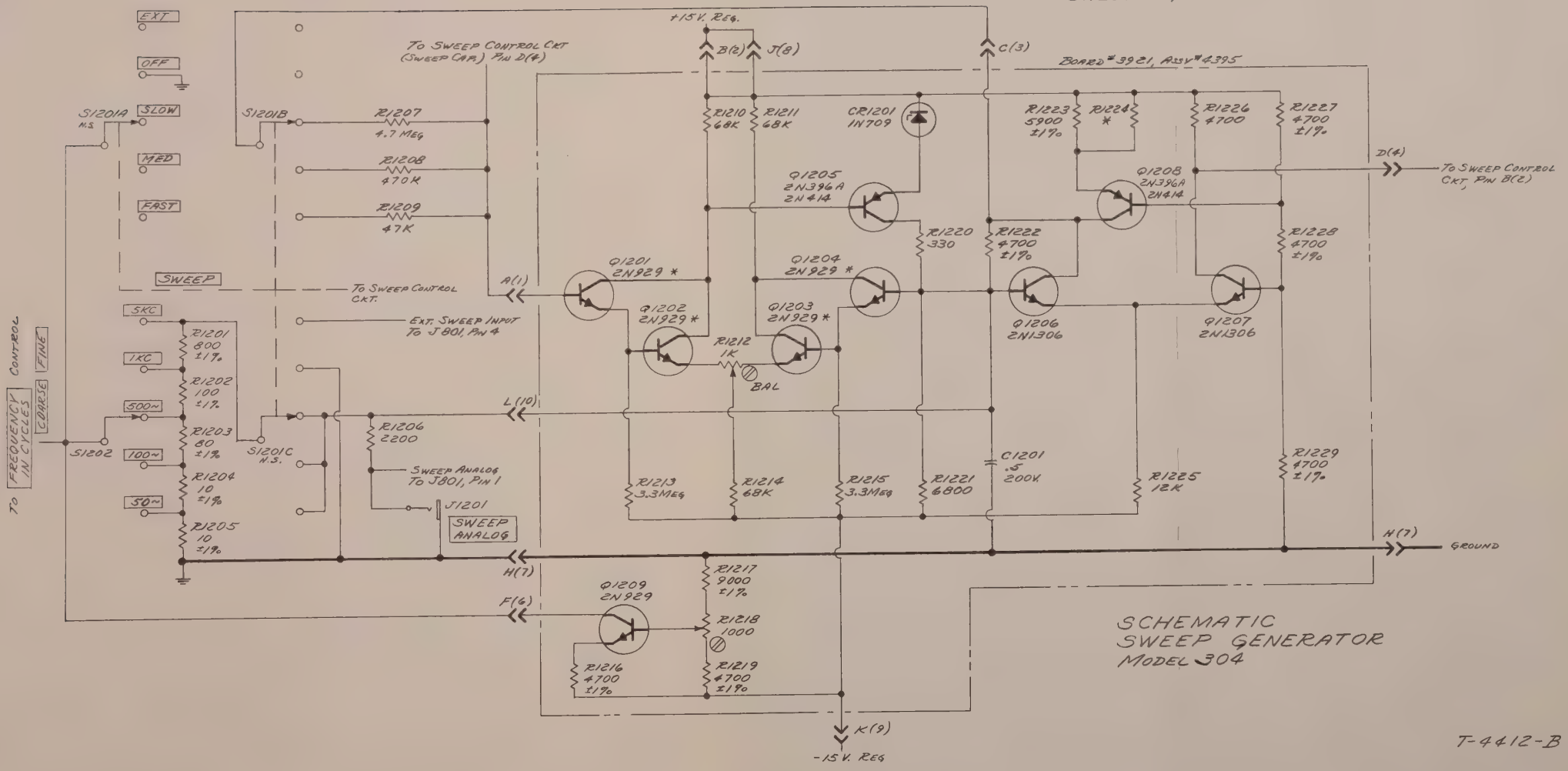
SCHEMATIC
METERING CIRCUIT
MODEL 304

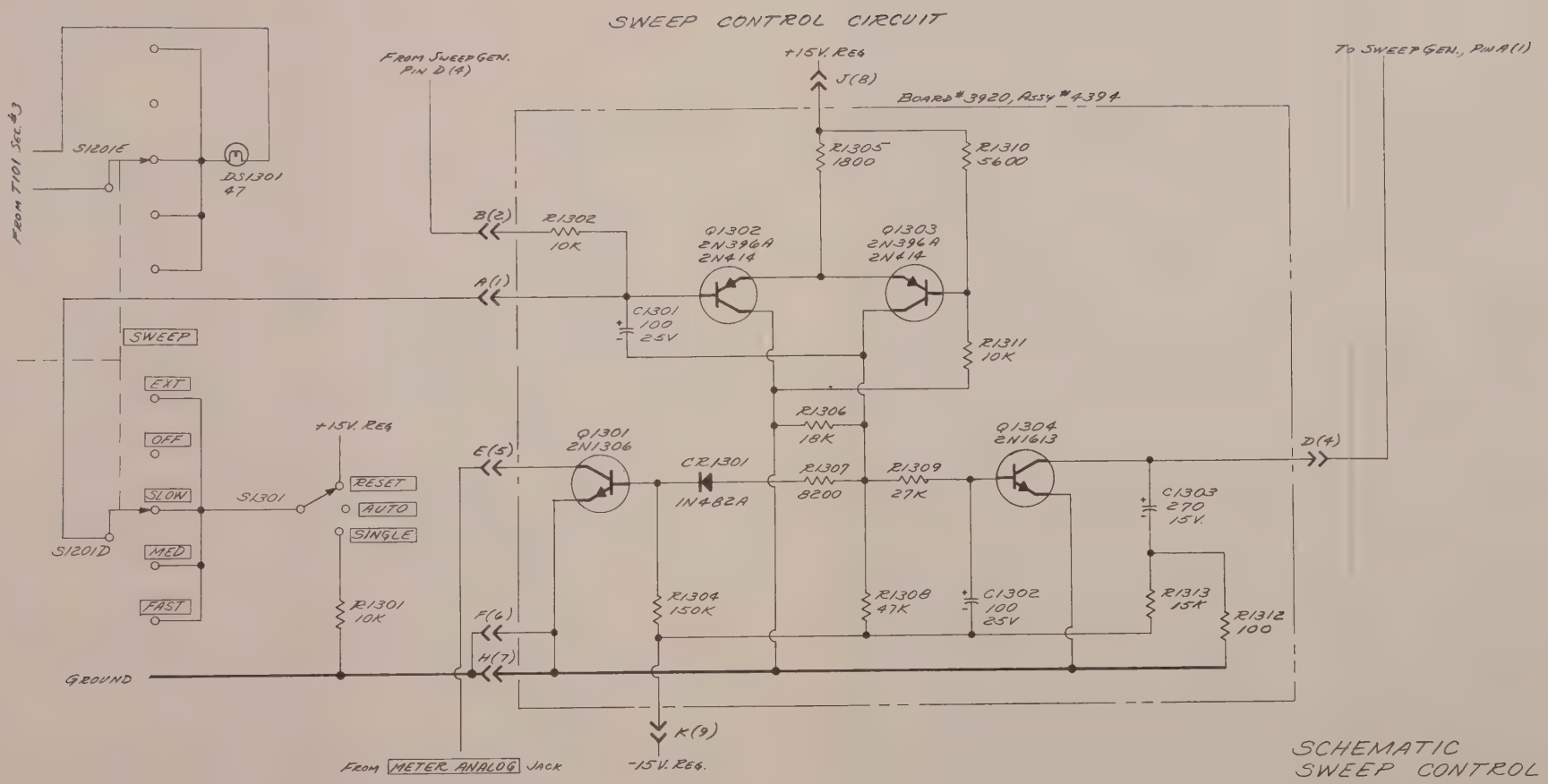
T-4410-C



SCHEMATIC
IMPEDANCE CONVERTER &
VARIABLE OSCILLATOR
MODEL 304

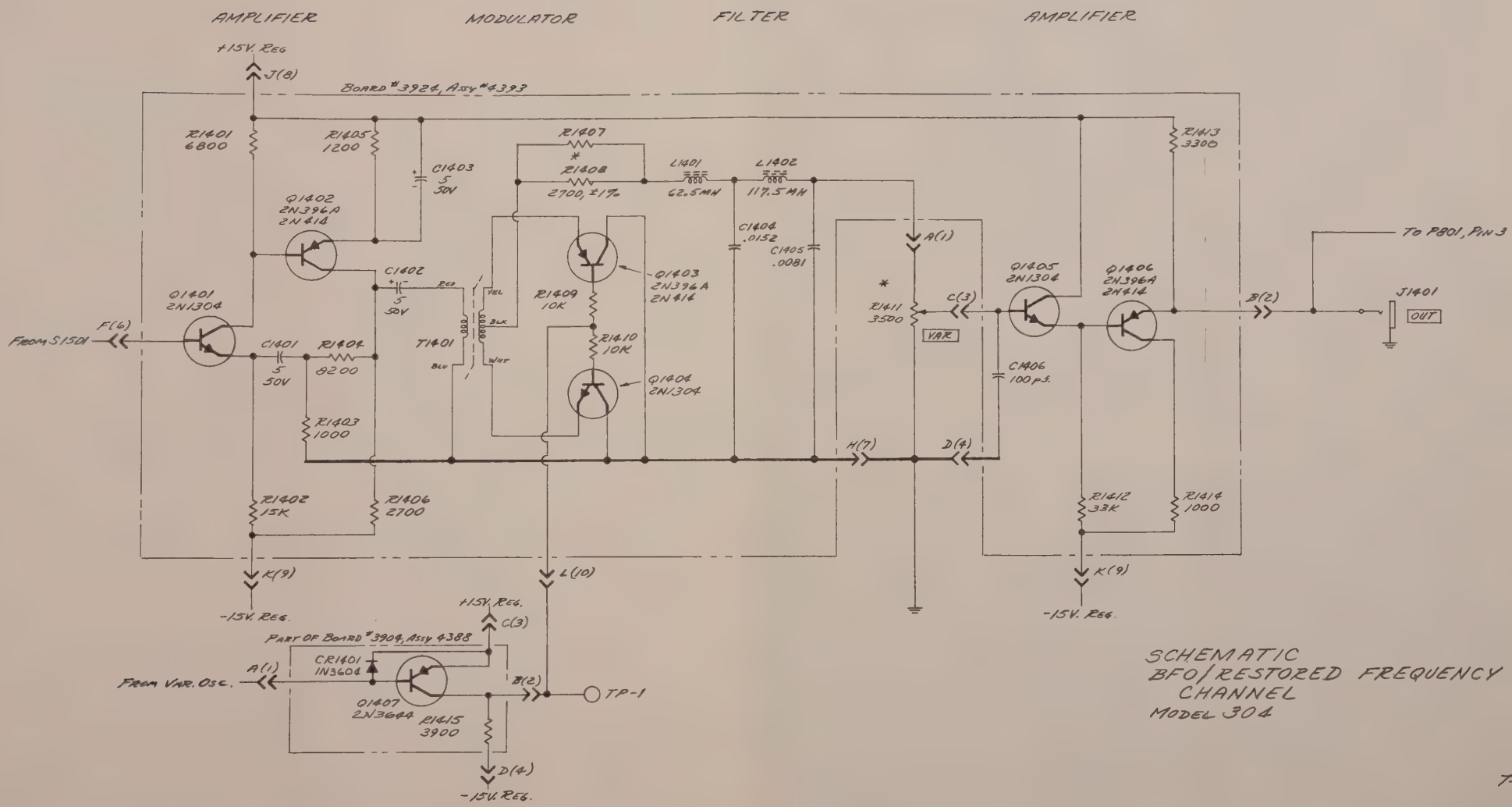
T-4411-G


SWEEP GENERATOR
EXT
OFF
SLOW
MED
FAST
S1201A M.S.
S1201B
S1201C M.S.
S1202
To FREQUENCY CONTROL
COARSE
FINE
SWEEP
SKC
1KC
500~
100~
50~
R1201 800 ±1%
R1202 100 ±1%
R1203 80 ±1%
R1204 10 ±1%
R1205 10 ±1%
R1207 4.7 MEG
R1208 470K
R1209 47K
To SWEEP CONTROL CKT (SWEEP CAB.) PIN D(4)
To SWEEP CONTROL CKT.
EXT. SWEEP INPUT To J801, PIN 4
R1206 2200
SWEEP ANALOG To J801, PIN 1
J1201
SWEEP ANALOG
+15V. REG.
B(2)
J(8)
C(3)
BOARD #3921, ASSY #4395
R1210 68K
R1211 68K
CR1201 IN709
R1223 5900 ±1%
R1224 *
R1226 4700
R1227 4700 ±1%
D(4)
To SWEEP CONTROL CKT, PIN B(2)
Q1205 2N396A 2N414
Q1208 2N396A 2N414
R1220 330
R1222 4700 ±1%
R1228 4700 ±1%
Q1201 2N929 *
Q1204 2N929 *
A(1)
Q1202 2N929 *
Q1203 2N929 *
Q1206 2N1306
Q1207 2N1306
R1212 1K
BAL
L(10)
R1213 3.3MEG
R1214 68K
R1215 3.3MEG
R1221 6800
C1201 .5 200V.
R1225 12K
R1229 4700 ±1%
H(7)
GROUND
R1217 9000 ±1%
F(6)
Q1209 2N929
R1218 1000
R1216 4700 ±1%
R1219 4700 ±1%
K(9)
-15 V. REG.
SCHEMATIC
SWEEP GENERATOR
MODEL 304
T-4412-B



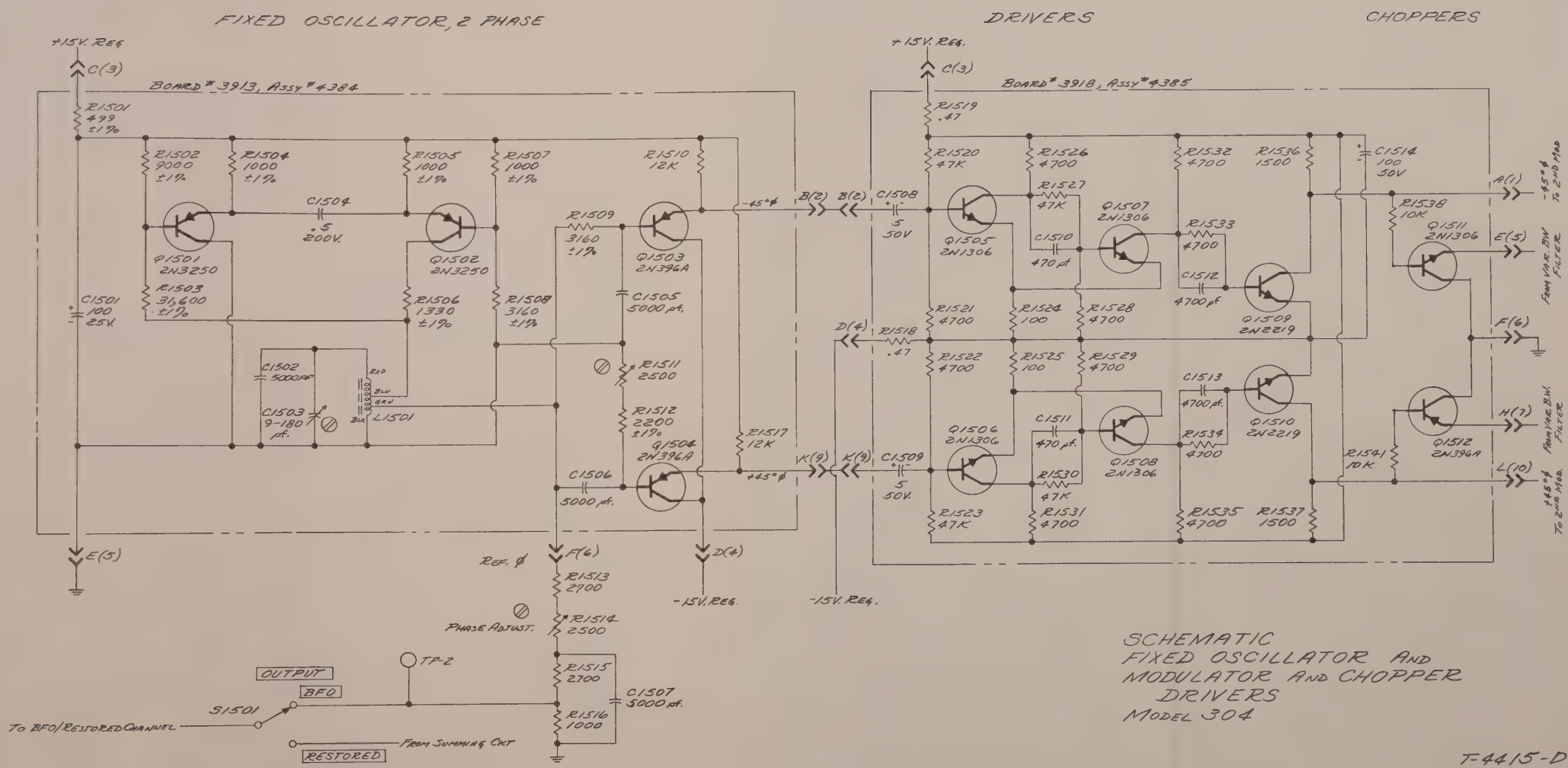
SCHEMATIC
SWEEP CONTROL CIRCUIT
MODEL 304

T-4413-C



SCHEMATIC
BFO/RESTORED FREQUENCY
CHANNEL
MODEL 304

T-4414-6



SCHEMATIC
FIXED OSCILLATOR AND
MODULATOR AND CHOPPER
DRIVERS
MODEL 304

T-4415-D

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